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TRIBULUS

Notes for Contributors

TRIBULUS is the Journal of the Emirates Natural History Group and was launched in 1991. The Group, based in Abu Dhabi, was founded in 1976 and is the oldest environmental non-governmental organisation in the United Arab Emirates.

It has three sister groups, the Al Ain ENHG, the Dubai Natural History Group and the Fujairah Natural History Group. Between 1976 and 1990, the Group published 42 issues of a thrice-yearly duplicated **Bulletin**.

Copies of **TRIBULUS** and of the Bulletin are available on the website of the Al Ain ENHG, at www.enhg.org

Between 1991 and 2006, **TRIBULUS** was published twice-yearly but from Volume 17 (2007), the number of pages has been increased and frequency has become annual, rather than bi-annual.

The aim of the publication is to create and maintain in standard form a collection of recordings, articles and papers on topics related to the natural history, heritage, geology, palaeontology, archaeology and history of South-Eastern Arabia, with the focus on the United Arab Emirates and adjacent areas.

Papers, short notes and other contributions are welcomed from both residents of the United Arab Emirates and others, but should not have previously been published elsewhere. Guidelines are set out below.

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All manuscripts received are reviewed by Editorial Board members and appropriate Advisory Panel members and, where appropriate, are also submitted for blind peer review.

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Photographs, line drawings and maps should be submitted, in electronic format, and should be of sufficiently high resolution to permit reproduction.

References should give the author's name, with the date of publication in brackets, showing title, publisher and country of publication, in date order. For journal articles, conventional abbreviations of journal titles may be used.

Scientific names should follow customary nomenclature in Latin while the common English names (if any) and local Arabic names (if available) should also be supplied.

TRIBULUS

Journal of the Emirates Natural History Group
Volume 24 - 2016

Contents

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Front: A juvenile hawksbill turtle on Webb Rock, a reef off the coast of Abu Dhabi's Western Region. *Picture by Veryan Pappin, Nautica Environmental Associates*

Back: An adult Egyptian nightjar (Caprimulgus aegyptius) at roost in Abu Dhabi, summer 2016. Breeding in the UAE was first confirmed in 2016. *Picture by Dr. Richard Hornby, Nautica Environmental Associates.*

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Editorial

This somewhat lengthy issue of ***Tribulus*** once again commences with a detailed paper by one of our most prolific, and most valued, contributors, Gary Feulner, who provides an extensive study of the flora of Fujairah's Wadi Wurayah protected area. While checklists of a particular category of fauna or flora covering the whole of the UAE (and, where appropriate, of adjacent areas of Oman) are always of value, in terms of enhancing knowledge of the country's overall biodiversity, it has long been our view that there is also much to be gained from more detailed studies of specific geographical areas. A focus on a designated reserve, such as Wadi Wurayah, of course, helps both to underpin its status and to inform recommendations for further work. It is to be hoped that further data on other aspects of this enormously important area will be made publicly available.

There is, as we have previously noted, an enormous amount of data on the UAE's biodiversity that has been collected during the course of various surveys carried out in the course of consultancy contracts. Such knowledge, however, is generally restricted to the companies commissioning the studies and to their clients and is not made available to the public. Thus the discovery several years ago of new species of bats for the Emirates, during a consultancy survey of an offshore island, has not been formally announced and these species, therefore, do not figure in the lists of the UAE's mammal fauna.

We accept that specialist consultants may feel constrained about divulging data because of contractual agreements. We would, however, urge environmental consultancy companies to engage more pro-actively with their clients to obtain approval for the release of as much data as possible. It is highly improbable, in our view, that much of the unpublished information is of any real sensitivity in commercial terms, while its publication could contribute, often significantly, to a better understanding of the UAE's biodiversity. Perhaps the setting out of a fixed period of time – a year or two? – at the end of which such data can be made public would be a sensible idea?

The other papers cover, as usual, a wide variety of topics, from fauna and flora to geology. Feulner and his colleagues Binish Roobas provide an update on their spider magnum opus from the previous issue of *Tribulus*, showing, once again, that there's always something new to discover, even in areas where much work has already been undertaken. The same is true of several other papers. David Chelnick *et al.* describe for the first time the exuvia (larva cases) of a rare dragonfly, *Urothemis thomasi,* recently identified in the Emirates. Peter and Elaine Cowan, from Oman, continue their investigations into the Arabian waterscorpion, a species also found here, confirming that – contrary to previous studies – it can fly, while the extent of published knowledge of the UAE's flora is expanded by the papers from Mohammad Shahid and N.K. Rao and by Sanjay Gairola and colleagues.

With a broader geographical focus, Victor Hitchings and Oscar Campbell report on the Arabian distribution of the Great Eggfly, with illuminating data on how a study of weather patterns can provide an explanation of unexpected occurrences of actively mobile species.

The weather, of course, isn't the only way in which species can spread beyond their normal range. Human activity also plays its part. Jacky Judas and Peter Hellyer summarise recent sightings of an exotic mammal, the Five-striped Palm Squirrel, which originally arrived in the UAE because of the trade in 'pets', but has now, as a result of deliberate releases or escapes, established itself across the country, with the potential to become a minor pest species. Tighter controls on the local pet trade have long been advocated, with little action, except on species deemed vulnerable or endangered, and the way in which these squirrels have become established and spread provides further evidence of the value of recording the presence in the UAE of all exotic species. A short note at the end of the journal calls for the submission of records for a UAE mammals database.

Finally, regular *Tribulus* contributors Graham Evans and Tony Kirkham present two more useful papers on the country's geology. One provides new data on the UAE's Pleistocene geology, from Yas Island. Their other paper is of a rather unusual type for the journal. Rather than being a scientific study, it is, instead, a specially-designed guide to enable interested, but under-informed, readers to undertake their own field excursion to three well-known mountains, Jebels Rawdhah, Buhays and Faiyah to examine some key geological strata and the marine fossils that are exposed there. We hope that readers in the UAE will make use of this guide to inform their travels and encourage them, of course, to report any data related to fossils, fauna, flora, archaeology and anything else that they may encounter while doing so.

Peter Hellyer

The Flora of Wadi Wurayah National Park, Fujairah, United Arab Emirates:

An annotated checklist and selected observations on the flora of an extensive ultrabasic bedrock environment in the northern Hajar Mountains

by Gary R. Feulner

Abstract

This study reports and comments on the results of a baseline survey of the flora of Wadi Wurayah National Park ("WWNP"), Fujairah, UAE, situated within the rugged Hajar Mountains of the UAE's East Coast. WWNP encompasses 221 square kilometres, including the entire watershed of Wadi Wurayah and much of Wadi Zikt, two of the largest and most remote wadi systems in the UAE, as well as the upper reaches of several neighbouring watersheds.

The protected area, and Wadi Wurayah in particular, has more permanent surface water than any other part of the Hajar Mountains of the UAE. For that reason it is home to a high proportion of the plant and animal species that can be found in the UAE mountain environment.

More generally, the northern Hajar Mountains is an important area from the perspective of regional plant biogeography because it is situated at the boundary of three major biogeographical zones — the Afrotropical, the Palaearctic and the Oriental — and three major phytogeographical regions — the Saharo-Arabian (Saharo-Sindian), the Sudanian (Nubo-Sindian) and the Irano-Turanian.

Within WWNP, the bedrock consists almost exclusively of igneous rock called harzburgite, originally formed exceptionally deep within the earth. The harzburgite bedrock has an unusual geochemistry, described as "ultrabasic", that can present special challenges to plant physiology. Ultrabasic environments elsewhere are associated with reduced plant diversity and high levels of endemism.

The baseline survey recorded more than 200 species of plants from within the area of WWNP, including one species new to the UAE. This total exceeds earlier informed estimates by one-third or more, moderating, although not negating, the prevailing view that the flora of the ultrabasic rocks of the Hajar Mountains is limited in diversity relative to more geologically conventional environments.

Comparison of the baseline survey results with published studies of nearby mountain areas indicates that WWNP has more than 70% of the number of plant species found at comparable elevations in the carbonate environment of the Ru'us al-Jibal range (the mountains of the Musandam peninsula), and may have *ca*. 8-12% more plant species than Wadi Hiluw, some 50 km to the south, which drains a watershed composed almost wholly of basic rock (gabbro). The latter finding casts doubt on the conventional wisdom that the ultrabasic environment alone is responsible for reduced floral diversity.

All eight Hajar Mountain endemic plant species found in the UAE were recorded within WWNP. The park is also an important site, and in some cases the only UAE site, for more than a dozen other rare or noteworthy plant species.

At the same time, a number of plant species common in other areas of the Hajar Mountains of the UAE and northernmost Oman appear to be absent within WWNP, suggesting that more focused study of WWNP and other areas of ultrabasic bedrock in comparison to neighbouring mountain areas has the potential to reveal previously unrecognised biogeographical patterns and/or ecological relationships.

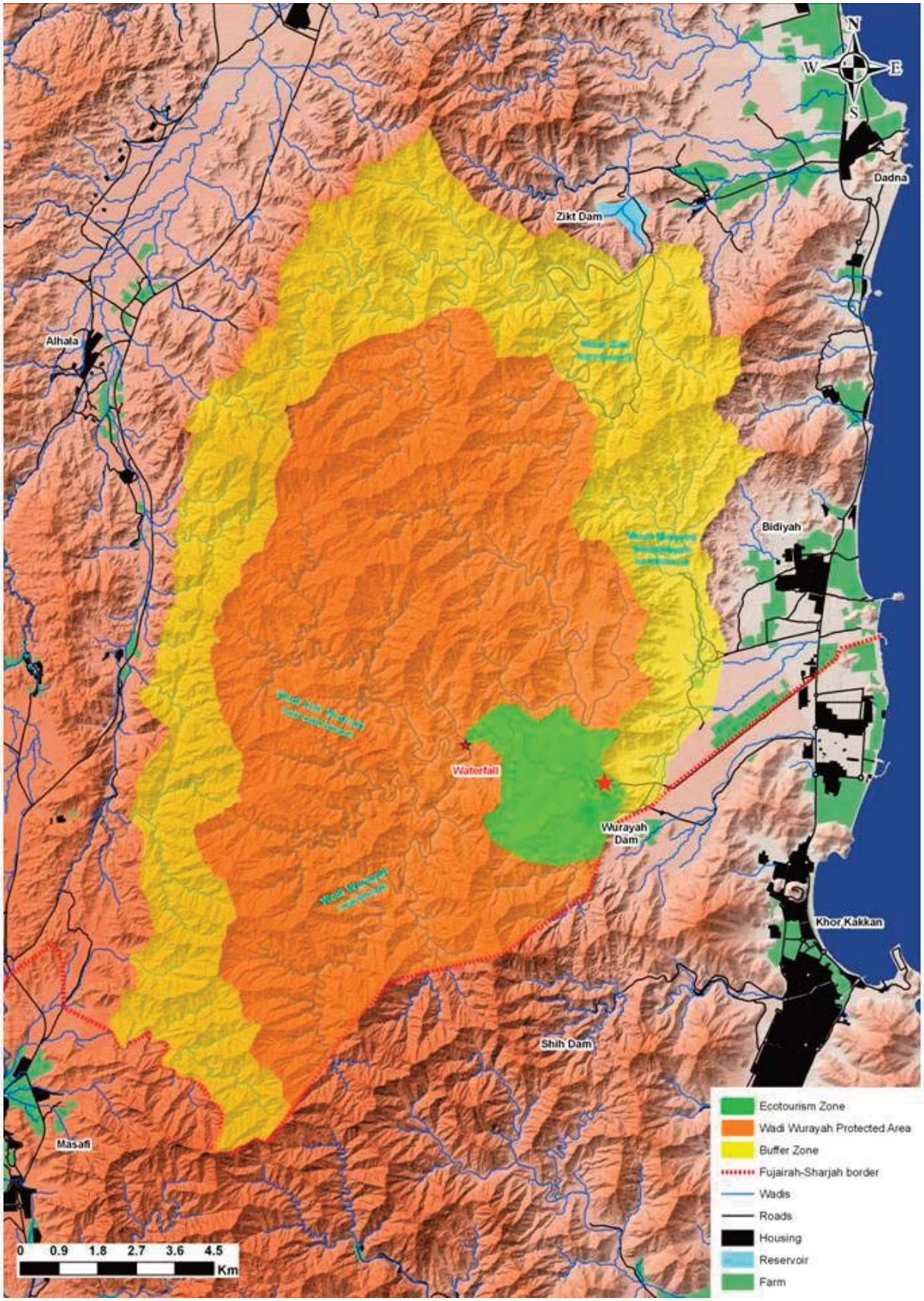
Index

Maps

Tables

Appendices

Figures



Map 1. Wadi Wurayah National Park.

Introduction

This study reports and comments on the results of a baseline survey of the flora of Wadi Wurayah National Park, Fujairah, United Arab Emirates (UAE), conducted by the author in 2013-2014 for Emirates Wildlife Society–World Wildlife Fund ("EWS-WWF") and sponsored by HSBC. The discussion and supplementary materials presented here reproduce the author's final report to EWS-WWF, dated 27 November 2014. The text of the original report has been edited only slightly, primarily to accommodate the journal format and to incorporate the subsequent records of two additional plant species found within the core zone of the park, as described in the text and in Appendix 1.

Wadi Wurayah National Park

Wadi Wurayah National Park (WWNP) was created by Decree No. 2 of 2009 of the Ruler of Fujairah, H.H. Sheikh Hamad bin Mohammad Al Sharqi, on 15 March 2009. It is located in the mountains of the Shimayliyah range along the East Coast of the United Arab Emirates (UAE) and constitutes the UAE's first mountain protected area.

The boundaries of WWNP are shown in Map 1. It encompasses almost the entire watershed of Wadi Wurayah (Arabic: وريعة *wu-RAY-ʿah*) as well as a large portion of neighbouring Wadi Zikt, to the north. These are two of the largest catchment areas in the Shimayliyah region. The National Park comprises a core protected area (the "core zone", shown in orange in Fig. 1) and a surrounding buffer zone (shown in yellow) which includes the adjacent mountain areas of upper Wadi Siji and upper Wadi Abadilah to the west, lower Wadi Zikt to the north, and Wadi Ghulayyil Khun to the east. The total area of WWNP is 221 square kilometres (equivalent to 12,700 hectares or 31,000 acres), including 129 square kilometres within the core area and 92 square kilometres in the buffer zone.

Wadi Wurayah was already well known by the early 1980s as the site of the UAE's only year-round waterfall, although it was then a full hour's drive from the coast by 4WD. It re-captured public attention again in the mid-1990s when it was proposed for protection by the Arabian Leopard Trust ("ALT") and Arabian tahr were discovered living there by ALT researchers Chris and Tilde Stuart. More recently the protection initiative was taken up by EWS-WWF, culminating in the historic declaration of WWNP. WWNP is overseen by Fujairah Municipality and was managed by EWS-WWF from 2012 through 2015.

Wadi Wurayah is justifiably acclaimed for its scenic beauty and its exceptional biodiversity. By virtue of its large size and its relative abundance of permanent water, it is home to a high proportion of the plant and animal species that can be found in the Hajar Mountains of the UAE.

More generally, the northern Hajar Mountains is an especially significant area from the perspective of regional biogeography because it is situated at the boundary of three major biogeographical zones the Afrotropical, the Palaearctic and the Oriental and three major phytogeographical regions the Saharo-Arabian (Saharo-Sindian) the Sudanian (Nubo-Sindian) and the Irano-Turanian.

WWNP is also largely free of the influence of human exploitation found in other UAE mountain areas. There are no current plantations within WWNP, little evidence of abandoned cultivation and only obscure evidence of ancient, very small scale hydro-engineering at a few locations on gravel terraces, so almost the whole of WWNP can be considered natural habitat. The silt accumulations behind the Wadi Wurayah dam are arguably an exception, but similar habitats can sometimes be created naturally, e.g., by landslides (Feulner 2004). A single farmstead used for goat husbandry, with minor associated agriculture, is located a short distance from the paved road in Wadi Wurayah, north of the dam. A few discrete sites (the Wadi Wurayah roadhead, trackhead and gorge, and waterfall picnic area) receive regular short-term human visitation.

Geography, geology and botanical implications

The Shimayliyah range, a sub-unit of the Hajar Mountains, lies between the cities of Fujairah in the south and Dibba in the north. It is bordered on the east by the coast, and on the west by the arc of wadis and roadways that connects (from south to north) the villages of Bithnah, Deftah, Masafi, Tayyibah, Uyaynah and Dibba.

The mountains of the Shimayliyah range are not especially high but they are extremely rugged. Three summits on the edge of WWNP (Jebel Masafi and its neighbour, Four Peaks, in the southwest, and Jebel Dad (a.k.a. Jebel Adhn) in the northwest) exceed 1100 metres, but these are exceptional. Few other summits and ridges within the area exceed 800-900 metres. However, the slopes are steep, the ridgetops are narrow, the bedrock is heavily fractured and the surface is often friable, making ascents extremely difficult in most places.

For comparison, the Hajar Mountains to the south of WWNP, from Wadi Ham (the Masafi-Fujairah road) southwards to Wadi Hatta (the Hatta road), include a number of ridgetop plateaux at 900-1050 metres (Feulner 2014). South of Wadi Hatta the central peaks are higher still, reaching 1400 metres or more almost all the way south to the Jebel Akhdar.

Geologically, the Shimayliyah area (and most of the Hajar Mountains southwards to the Jebel Akhdar) represents a thick slice of the earth's mantle that has been detached and thrust to the surface by tectonic forces. The predominant rock type is an igneous rock called harzburgite, a chemically altered form of normal mantle rock, depleted by partial melting and fractionation at depth. Mantle rock is very low in silica

(SiO_2) relative to most igneous rocks. Geologists refer to the various low-silica mantle rock types, including harzburgite, as "ultrabasic" rocks or "ultrabasics".

The term "ophiolite" has been used historically to refer to the suite of ultrabasic mantle rocks and associated rock types from the overlying oceanic crust (gabbro and pillow lavas) that is found as a minor element of many mountain belts worldwide, but a significant one, because it represents the remnants of a former ocean basin closed by subduction. The Hajar Mountains comprise the world's largest surface exposure, by far, of an association of such rocks. These have been called by various names including the Hajar Mountain ophiolite, the Semail ophiolite and the Semail nappe.

Within WWNP, the bedrock is almost exclusively harzburgite (Boeuf *et al*. 1974; Ball *et al*. 1988; British Geological Survey 2006; Goodenough *et al*. 2006), with the exception of a few small localities of dunite (another ultrabasic rock) and rare dikes (intrusive veins or sheets) of granite (a high-silica or "acidic" igneous rock) (British Geological Survey 2006; Goodenough *et al*. 2006). A number of larger granite dikes are found in the area of the divide between Wadi Zikt and the Wadi Ghayl branch of Wadi Wurayah. The granite dikes are conspicuously grey, in contrast to the reddish brown weathering harzburgite.

To the south of the Shimayliyah range, occupying roughly the southeast quadrant of the Hajar Mountains within the UAE, is an area that consists mostly of gabbro, an igneous rock with intermediate silica content (called "basic" by geologists), representing former oceanic crust. To the north of the Shimayliyah range lie the mountains of the Musandam peninsula, the Ru'us al-Jibal range, which consists of a 2,000 metre thick sequence of mostly shallow water carbonate sediments (limestone and dolomite).

These geological and geochemical distinctions are not merely of academic interest. Ultrabasic bedrock is associated with distinctive soil chemistry (e.g., low calcium, nitrogen and phosphorus, high magnesium and heavy metals, and hyperalkaline groundwater) which is often reflected in distinctive flora, including the evolution of races or species that are confined to ultrabasic substrates (Harrison & Kruckeberg 2008). These include species that selectively accumulate heavy metals, perhaps as a deterrent to predators, as well as others that have evolved mechanisms to restrict excessive metal uptake (Ghaderian & Baker 2007; Harrison & Kruckeberg 2008). (See also the discussion in Feulner (2011), at Section 6.2, pp. 75-76.)

Within the Hajar Mountains, ultrabasic bedrock is associated with distinctive physical and physiographic properties as well as geochemical ones. Harzburgite tends to fracture readily, weathering into shards, and to form steep or vertical faces above slopes littered with talus or scree. Gabbro bedrock, by contrast, is more coherent and weathers in a blocky fashion. Among the practical differences from the point of view of field studies is that gabbro slopes are generally somewhat less steep and easier to ascend.

It has been asserted or implied that botanical diversity is lower within the ophiolite rocks of the Hajar Mountains than in the areas of carbonate bedrock, especially the Jebel Akhdar and the Jebel Bani Jabr (Munton 1985, Insall 1999). That has not been controverted, as far as the author is aware, although the difference may not be due to geochemistry alone. But no study has yet specifically examined either the influence of the ophiolite substrate on the distribution of plant species within the Hajar Mountains or the influence of the ultrabasic substrate on their distribution within the ophiolite. However, the major gabbro areas in the UAE are now recognised to host an association of plant species that differs in a number of respects from that of ultrabasic areas (Feulner 2014; see Observation 9.5 below).

The Shimayliyah region represents the northernmost extent of the ophiolite. To the north, across the Dibba plain (the alluvial fan of Wadi Basairah), lies the carbonate sedimentary massif of the Ru'us al-Jibal. To the west and southwest the ultrabasics of Shimayliyah are bordered, respectively, by the distinctive fringing metamorphic rocks of the Masafi-Tayyibah and Wadi Limarit areas. To the south, as noted above, they are bordered by extensive areas of gabbro within the ophiolite. By virtue of its location, therefore, WWNP presents botanists with an excellent opportunity to study the possible influence of geology, and in particular the influence of ultrabasic geochemistry, on plant diversity and distribution within Eastern Arabia.

Climate and rainfall

The climate and rainfall of the Shimayliyah area are briefly described in EWS–WWF (2006, at Section 3.2, pp. 20-21) and Tourenq *et al*. (2009), based on data from four meteorological stations flanking the area, at Masafi, 'Asimah, Khor Fakkan and Ghayl. Temperatures are relatively high. For Masafi, a long-term mean of 26.8°C is given, with a low monthly mean of 11.4°C in January and a high monthly mean of 43.0°C in June. Winter temperatures on the East Coast (including the coastal mountains) average about 2°C higher than in most of the rest of the UAE (UAE University 1993).

Relative humidity varies widely but the mean for the mountain regions of the UAE's East Coast is 50-60% (UAE University 1993). That figure is somewhat higher, perhaps as much as 10% higher, than for the mountain regions farther inland, to the west and to the south (UAE University 1993, EWS–WWF 2006, Tourenq *et al*. 2009). Relative humidity is generally greatest in autumn and winter, and lowest in spring and summer (UAE University 1993, EWS–WWF 2006, Tourenq *et al*. 2009).

Rainfall is extremely variable but low overall, although the mountains of the Masafi area have long been recognised as the wettest area of the UAE. The

composite 30-year (1975-2004) average for the four meteorological stations listed above is approximately 160 millimetres/year (Feulner 2011), corresponding to a "semi-arid" regime. The long-term records for Masafi show a mean of 179 millimetres annually, with a minimum of 27.6 millimetres in 1985 and a maximum of 443.8 millimetres in 1976 (UAE University 1993).

Rainfall is correlated at the above four stations and is also correlated with rainfall throughout the UAE generally (Feulner 2006b). Rainfall records appear to show a cyclical pattern (EWS–WWF 2006, Feulner 2006b, Tourenq *et al*. 2009) that is correlated with the El Niño phenomenon, UAE rainfall being highest in El Niño years (EWS–WWF 2006, Tourenq *et al.* 2009).

Rainfall is generally greatest in winter (December through March). Summer rain is normally associated with thunderstorm activity. The winters of 2012-13 and 2013-14 were both wetter than average. Prior to commencement of the baseline survey, rain had fallen in mountain areas in each month from September to December 2012. Heavy rain fell in mid-December 2012 and again at the end of April 2013. The latter was reportedly associated with cloud-seeding efforts. Autumn rain was limited in 2013 but rain fell on several occasions in January 2014**.** Exceptionally heavy rain fell again in mid-March 2014, filling the basin and wadi behind the Wadi Wurayah dam to within ca. 250 metres of the lower road crossing. Rain fell again in late October 2014 and a major flash flood occurred in Wadi Wurayah on 1 November, a few days before the last field visits undertaken for the baseline survey.

The baseline survey and annotated checklist of the flora of WWNP

History of botanical investigation in and around WWNP

The mountains of the Shimayliyah area were described in the first published flora of the UAE (Western 1989) as "wild and almost inaccessible . . ." and were identified as "an under-explored area as far as botany is concerned". Access has since improved but the area has remained under-explored botanically until the baseline survey reported here.

The author first visited Wadi Wurayah in the mid-1980s. Since early 1992, he has returned intermittently to explore areas now within WWNP for the express purpose of botanical and other natural history investigation. The dates and locations of those historical visits, totaling 20 field days, are shown in Table 1A.

During the winters of 1994-95 and 1995-96, naturalist consultants Chris and Tilde Stuart of South Africa conducted wildlife surveys in Wadi Wurayah on behalf of the Arabian Leopard Trust ("ALT"). Their efforts produced important zoological data (including the discovery of Blanford's Fox and Arabian tahr) but they paid only limited attention to the flora.

Based in part on the Stuarts' results, the creation of a national park in the Shimayliyah range, centred on Wadi Wurayah, was proposed by the ALT (Jongbloed 1996). A provisional management plan for the proposed park was also prepared (Hornby 1996), including checklists of fauna then known or expected to occur within the Shimayliyah range.

The provisional management plan also includes a brief discussion of the flora within the area of the proposed national park (Hornby 1996, at 7-8) [updated botanical nomenclature is shown in brackets]:

> The high temperatures, the extreme aridity for most of the year and the violence of the infrequent rain events make the mountains a difficult place for plant growth. There is therefore a great deal of bare ground. The dominant species tend to be low-growing woody perennials, obviously well adapted to surviving high temperatures and periods of drought. In shady situations or in wadis where the water table is high for most of the year, a wider range of plant species is able to grow. Many annual species appear after rain, and the mountains can be relatively green and flowery at such times.
>
> . . . . The total number of plant species growing in the proposed national park is likely to be of the order of 120 to 150.
>
> The most characteristic perennial species include:
>
> *Tephrosia apollinea*
> *Taverniera glabra* [=*T. cuneifolia*]
> *Crotalaria aegyptiaca*
> *Astragalus fasciculifolius*
> *Ochradenus aucheri*
> *Euphorbia larica*
> *Nerium mascatense* [= *N. oleander*]
> *Forsskaolea tenacissima*
> *Indigofera oblongifolia* [*sic*]
> *Fagonia indica*
> *Cassia italica* [= *Senna italica*]
> *Aerva javanica*
> *Asphodelus tenuifolius*
> *Heliotropium calrareum* [= *H. brevilimbe*]
> *Pulicaria nobilis* [= *P. edmondsonii*]
>
> and the trees:
>
> *Ziziphus spina-christi*
> *Acacia tortilis*
> *Prosopis cineraria*
> *Ficus salicifolia* [= *F. cordata salicifolia*]
> *Moringa peregrina*

Two species regarded as of particular interest are the orchid *Epipactis veratrifolia* and the fern *Onychium divaricatum*. These are two of the species likely to be an attraction to future 'ecotourists'.

There are probably several species of plant which are endemic to the mountains of the UAE and and these would represent an important element of the biodiversity of the region. There is a great need for work to document the distribution of mountain plants, both in the UAE and as a whole. Co-operation with the newly formed Plant Group of Arabia, convened under the auspices of IUCN, is strongly recommended.

Much of the information accumulated through the foregoing efforts was incorporated in Jongbloed *et al.* (2000) and Jongbloed (2003). The author was actively involved in providing information and photographs for use in Jongbloed (2003) and reviewing and commenting on the accounts of species found in mountain areas.

In 2006, at the request of EWS–WWF, the author prepared and contributed a compilation of his records of flora and selected fauna from historical visits to Wadi Wurayah and its tributaries (Feulner 2006a), for use in connection with a study sponsored by HSBC to evaluate the prospective creation of a protected area. The list of flora was acknowledged to exclude many annuals and most grasses (Poaceae) that might potentially occur (the author was at that time still inexperienced in the identification of grasses), but it nevertheless included *ca.* 87 species.

The final study report (Emirates Wildlife Society-WWF 2006) relied more heavily on a January-March 2006 field survey of plants by EWS–WWF volunteers. It lists, in Appendix 3, 27 species said to have been "the major plants found in the area", but a number of the species listed are problematic in light of both prior and subsequent information. In particular, the records and/or accounts of *Cyperus conglomeratus*, *Cymbopogon commutatus*, *Lycium shawii* and *Fagonia indica* must be regarded sceptically, and the record of *Tamarix aphylla* is known to be erroneous – and was in any case from another wadi to the south, not Wadi Wurayah (C. Tourenq, *pers. comm.*).

Notwithstanding the foregoing criticism of botanical identifications, the HSBC-sponsored report is in many other respects one of the best sources of general information currently available about UAE mountain wadis, especially for hydrology. The results of that study were subsequently published for a broader audience, with selected additional information and commentary (Tourenq *et al*. 2009).

The "Flora" section of the original report (Emirates Wildlife Society–WWF 2006) was republished intact in Tourenq *et al*. (2009), except that it was unwisely introduced in the latter by the additional statement that "Wadi Wurayah hosts about 300 plant species." That statement was attributed only to an unpublished report and is clearly erroneous, but it has nevertheless been repeated and continues to appear in print and internet sources, including Wikipedia (Wikipedia – "Wadi Wurayah").

The author's own study of the flora of the Ru'us al-Jibal range (the mountains of the Musandam peninsula) (Feulner 2011) expanded the number of species known from the UAE and Northern Oman, facilitated the resolution of several instances of synonymy, and established a basis for comparison with the flora of other mountain areas.

The baseline survey

The current survey consisted of botanical excursions on foot within WWNP, comprising a total of 33 field days between 15 December 2012 and 4 November 2014, as detailed in Table 1B. Field work included visits during eleven different months of the year but was concentrated in December 2012, January, March and August 2013, and March 2014.

In addition to the current survey data, this report and the accompanying Checklist incorporate the botanical results of historical natural history investigations by the author, shown in Table 1A, amounting to 22 field days between March 1992 and January 2012, including several remote areas not reached by the current survey.

The geographical coverage of the current survey and those historical visits is shown in Map 2. The overall coverage is extensive but investigation of summit ridges, passes and uppermost slopes and wadis was more limited. At least eighteen excursions explored terrain lying at *ca.* 400 metres or more, but only ten excursions reached elevations exceeding *ca.* 550 metres and only five of those reached or exceeded *ca.* 700 metres (the summit of Jebel Masafi, two traverses of the pass from Wadi Siji to Wadi Murtaqam, the traverse from Wadi Abadilah to Wadi Yushemah, and the pass at the head of the SW branch of Wadi Zikt). This reflects the difficulty of the summit terrain within the ultrabasic environment of WWNP.

The Checklist also relies on information contained in selected literature sources as well as unpublished documents available to the author. Those are indicated by citations.

Almost all identifications were made by the author, based on field experience in the UAE and Oman (see, e.g., Jongbloed (2003) and Feulner (2011)) and reference to Boulos' *Flora of Egypt* (Boulos 1999, 2000, 2002 and 2005), Ghazanfar (2003, 2007, *in press*), Cope (2007) and Karim & Fawzi (2007). Most determinations could be made with confidence. Selected details are discussed in individual Checklist entries. Marijcke Jongbloed identified *Zaleya pentandra* and Norbert Kilian identified *Launaea omanensis*, in each case from the author's photographs.

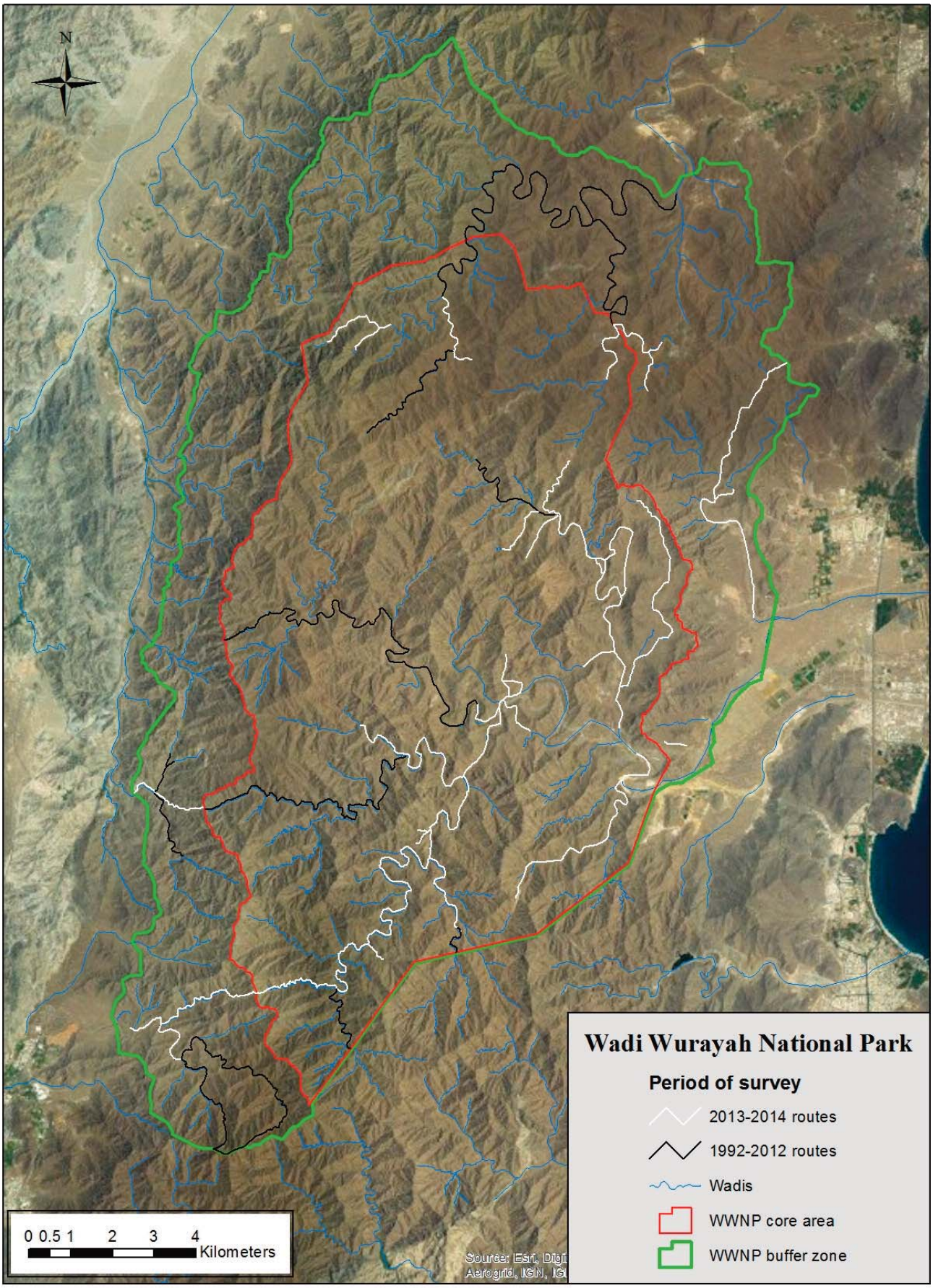
The nomenclature used in the Checklist follows Jongbloed (2003), as amended pursuant to Ghazanfar (2003, 2007, *in press*, *in prep.*) and Feulner (2011).

Table 1A: Historical field excursions by the author within the boundaries of WWNP

Date(s)	Route or location
27-03-92	Waterfall Branch, to pass overlooking W. Abadilah (w/ C.S. Laubach)
21-05-93	W. Wurayah SE Fork (W. Aqabat) (w/ C.S. Laubach)
15-01-94	W. Zikt, Nimriyah Branch
26-10-95	W. Yashimah (Ghashemah) (w/ M. Parker)
27-10-95	W. Wurayah and main S branch (W. Murtaqam) (w/ M. Parker)
29-12-95	Traverse from upper W. Siji (ca. 700m) into W. Murtaqam (w/ I. Robson)
06/07-12-96	Wadi Murtaqam (upper) (w/ M. Parker)
28-02/01-03-97	W. Zikt, SW Branch (solo overnight)
30-03-97	W. Ghayl (full) (w/ M. Sawaf)
28-03-98	Upper W. Siji to summit of Jebel Masafi (1100+m) (w/ I.R. Curtis)
25-11-00	W. Wurayah (w/ S. Green)
10-10-03	Traverse of W. Yashimah from W. Abadilah (w/ J. Burt & A.S. Gardner)
18-10-03	W. Abadilah, E Branch, N Fork
24-10-03	W. Abadilah, E Branch, S Fork
30-05-08	W. Wurayah waterfall & pools area (w/ N. Karki)
07-08-09	Scout W. Wurayah waterfall area for *Saccharum kajkaiense* (w/ N. Karki)
18/19-01-12	W. Zikt SW Branch to pass (ca. 700m) (w/ M. Shuriqi & M. Sawaf)
12/13-09-12	W. Wurayah + W. Murtaqam to Ghalil al-Haban (w/ M. Shuriqi & M. Sawaf)

Table 1B: Field excursions undertaken for the WWNP baseline flora survey

Date(s)	Route or location
15-12-12	W. Ghayl (lower)
16-12-12	Waterfall Branch (lowest)
	W.Wurayah gorge + lowest W. Yashimah
20-12-12	W. Zikt, Nimriyah area
21-12-12	W. Wurayah
04-01-13	W. Wurayah SE Fork (W. Aqabat)
05-01-13	Dunite Terrace + W. ad-Dhahir to pass (*ca*. 430m)
11-01-13	W. Abadilah (upper)
	W. Wurayah dam basin
12-01-13	Dam Wadi to granitic dike below pass, via bedrock fork (ca. 500m)
23-01-13	W. Yushimah + W.Ghalan
24-01-13	W. Ghayl to Blue Water
01-03-13	Parking Lot Wadi
02-03-13	W. Ghayl to Aqabat Kharus
08-03-13	Blue Water Fork to pass (*ca*. 460m)
09-03-13	Dunite Terrace + W. ad-Dhahir (re-visited)
	W. Wurayah waterfall area
	Dam basin + Dam Wadi (lower) (re-visited)
15/16-03-13	Traverse from upper W. Siji (ca. 700m) into W. Murtaqam + exit via W. Wurayah
08-06-13	W. Wurayah waterfall area (re-visited)
	Dunite Terrace + W. ad-Dhahir (re-visited)
	Parking Lot Wadi (re-visited)
09-06-13	W. Zikt, Nimriyah area, traverse pass to W. Ghayl (ca. 400m)
10/11-06-13	W. Wurayah + W. Murtaqam to Ghalil al-Haban
19-08-13	W. Zikt, SW Branch, W Fork (by helicopter)
20-08-13	W. Zikt, SW Branch (by helicopter)
21-08-13	W. Ghayl, Camera Fork (W of Blue Water Fork)
05-12-13	W. Ghulayyil Khun
20-01-14	WWNP Headquarters (HQ) area + dam basin
21-01-14	W. Zikt, SW Branch, W Fork (by helicopter)
08-03-14	W. Ghayl, pass to W. Zikt
11-03-14	Upper W. Siji
14-03-14	Powerline Fork, W. Ghayl
16-05-14	Dam Wadi to granitic dike below pass, via scree fork (ca. 550m)
23-05-14	Waterfall Branch (lowest) + Dunite Terrace + W. ad-Dhahir
18 & 25-07-14	Powerline Fork, W. Ghayl
26-07-14	W. Ghayl branch (lower)
04-11-14	W. Wurayah waterfall and reed pools above gorge



Map 2. Field coverage represented by the baseline survey and historical field excursions by the author.
(Map courtesy of J. Judas)

The Checklist

On the basis of survey data and historical records, an annotated checklist ("the Checklist") has been prepared in digital format using Microsoft Office Excel 2003. All species of vascular plants recorded within the area of WWNP are included. The default organisation of the Checklist is by Order and Class in traditional taxonomic order, then by family, genus and species alphabetically.

For each species, the following information is entered:

- Family
- Genus
- Species
- Authority for nomenclature
- Growth and form (annual/perennial, prostrate/erect, herb/shrub/tree, etc.)
- Abundance
- Habitat (primary = 1, secondary = 2)
  - Wadi pools
  - Wadi bed and bank
  - Wadi slope
  - Gravel terrace
  - Gravel terrace (silt accumulations)
  - Gulleys
  - Stony slopes
  - Rocky slopes
- Remarks

A printed version of the Checklist is appended to this report as Appendix 1, showing all of the above categories. A key to the abbreviations used is given at the end of the Checklist.

For convenience, an alphabetical list of species has also been prepared from the Checklist and is included in this report as Table 2A, showing genus, species, family and remarks.

The Checklist can be readily expanded to add, at a later stage, additional categories of data, including, e.g., global range, regional range, UAE Red Data List status, geographic coordinates of important sites, and traditional uses.

Selected Observations on the Flora of Wadi Wurayah National Park

The principal purpose of the baseline survey was to produce the Checklist. Nevertheless, it is appropriate and valuable also to provide an indication of the nature and significance of the results and to highlight a number of specific facts and generalisations relevant to a better appreciation of the flora of WWNP.

To that end, a number of selected observations are set out below in summary fashion. Many of these are worthy of further investigation and/or elaboration.

1. Abundance and diversity.

Table 2A lists alphabetically, with selected annotations, 206* plant species that have been recorded within the boundaries of WWNP, including both the core zone and the surrounding buffer zone. The list includes:

- 178 species (86%) recorded from within the core zone, either by the current survey or historically.
- 28 species (14%) recorded only from within the buffer zone, either by the current survey or historically. For convenience, those records are also listed separately in Table 2B.
- 19 species (9%) represented by historical records only, i.e., species previously recorded from within the area of WWNP (core zone or buffer zone) but not recorded during the current survey. For convenience, the historical records are also listed separately in Table 2C.
- 17 species (8%) represented by records of single plants only, whether current or historical. This is indicated by annotations in Table 2A. An additional 8 species are represented by historical records from which it cannot be determined whether more than a single plant was observed.

Appendix 1, the Checklist, presents a more fully annotated tabulation of all of the above-mentioned species, by family, including an indication of growth form, a qualitative assessment of abundance and preferred habitat(s), and selected remarks.

[**After submission of the final survey report in November 2014, a 207th plant species,* Indigofera coerulea (Fabaceae)*, was recognised by the author within the core zone of WWNP, and a single specimen of* Paracaryum intermedium (Boraginaceae) *was recognised from within the core zone (in addition to the buffer zone) from a photograph taken during the survey. These records have been incorporated in Tables 2A, 2B and Appendix 1, but they are not included in the statistics presented in this paper.*]

1.1. Some quantitative data and comparisons.

1.1.1. Exclusion of four introduced exotic species. The statistics presented below are based on the list of species in Table 2A, but *excluding* the records of four introduced exotics: *Citrullus lanatus* (Cucurbitaceae, the cultivated watermelon), *Ficus religiosa* (Moraceae, the peepul tree), *Solanum lycopersicum* (Solanaceae, the cultivated tomato) and *Mangifera indica* (Anacardiaceae, the cultivated mango). None of those four species have become or are likely to become established in WWNP.

1.1.2. Gross totals. So tabulated, WWNP, including its buffer zone, is home to at least 202 native species of higher terrestrial plants, representing 53 families and 163 genera, as detailed in the accompanying Checklist. This amounts to more than one-quarter of the ca. 720+ species of higher terrestrial plants recorded to date for the UAE and adjacent areas of Northern Oman. (For a discussion of some of the difficulties of calculating the exact number of plant

species recorded in the UAE, see Feulner (2011) at Section 1.1., pp. 32-34.)

These totals exceed previous informed estimates by one-third or more, moderating although not negating the prevailing view that the flora of the ultrabasic rocks of the exhibits limited diversity relative to more geologically conventional environments. Moreover, it is inevitable that additional species, both anticipated and unanticipated, will be added to the list over the course of time.

1.1.3. Family level diversity and regional comparisons. The families best represented in WWNP, in terms of numbers of species, are Poaceae (30 spp.), Asteraceae (20 spp.) and Fabaceae (13 spp.). A small majority of the families present are represented by more than one species (29 of 53 families, or 55%); 24 of the 53 known families (45%) are represented by only a single species.

The top three families (Poaceae, Asteraceae, and Fabaceae) also hold the top three positions within the flora of the neighbouring Ru'us al-Jibal range (Feulner 2011) and the nearby Wadi Helo Protected Area (El-Keblawy 2011), as well as the florae of the UAE (Jongbloed *et al*. 2000) and Oman (Ghazanfar 1992b) as a whole (Table 3). Six additional families (Boraginaceae, Brassicaceae, Caryophyllaceae, Euphorbiaceae, Lamiaceae and Scrophulariaceae) appear in the top dozen in each list.

1.1.4. Genus level diversity. Only 28 of the 163 genera present in WWNP, or about 17%, are represented by multiple species; 135 genera (83%) are represented by just a single species. The best represented genera are: *Launaea* (5 spp., but none is common, one is rare, and one is a sole record); *Plantago* (4 spp., all common or occasional annuals); *Cleome* (4 spp., but none is common and one is at the limit of its range and is very rare); and *Eragrostis*, *Euphorbia* and *Salvia* (each with 3 spp.). 22 genera (14%) are represented by 2 species each. At the genus level, therefore, taxonomic diversity is high and taxonomic concentration is low.

1.1.5. Qualitative assessment of species abundance. The Checklist includes a qualitative assessment of the abundance of each species, on a scale of Hyperabundant (H), Common (C), Locally Common (L), Occasional (O), Rare (R) and Exceptional (E). Only four species have been designated as "Hyperabundant": the tall perennial reed *Arundo donax* and three annuals – the lily *Aphodelus tenuifolius*, the blue pimpernel *Anagallis arvensis*, and the dock *Rumex vesicarius*. Otherwise, the numerical results are distributed over a rough bell curve from Common (27 species) through Locally Common and Occasional (combined 87 species) to Rare (65 species) and Exceptional (23 species).

As used here the foregoing terms have not been assigned specific operational definitions. Rather, they are used in a common sense way to convey a reasonable expectation of the likelihood that an observer looking in a suitable habitat at a suitable time will find the species in question.

"Common" species can often be seen simply by glancing at a suitable habitat, or for smaller species, by a short walk across it. Examples include trees such as *Acacia tortilis*, the wadi fig *Ficus cordata salicifolia* and the *sidr* tree *Ziziphus spina-christi*, small to medium shrubs such as *Convolvulus virgatus*, *Euphorbia larica*, *Lavandula subnuda* and *Leucas inflata*, prostrate perennials such as *Fagonia brugueri*, grasses such as *Cenchrus ciliaris* and the wadi bed tussocks of *Saccharum griffithii*, and annuals such as the prostrate *Aizoon canariense* and *Argyrolobeum roseum* and the erect *Diplotaxis harra* and *Silene austroiranica*.

"Locally Common" species can sometimes be abundant over modest areas but are otherwise normally Occasional or Rare. Examples include the prostrate annuals *Plantago ciliata*, *Plantago ovata* and *Tribulus terrestris*, which can proliferate on gravel terraces, the erect annuals *Cleome noeana*, *Euphorbia arabica* and *Reseda muricata*, which may multiply in gravel wadis, the small shrubs *Gymnocarpos decandrum* and *Ochradenus aucheri*, which sometimes cluster at the base of rolling slopes, and the larger, gulley-loving shrub *Dodonaea viscosa*.

"Occasional" species would normally be seen during the course of a day's outing, but typically only as scattered individual specimens. Examples include perennial shrubs such as the delicate but spiny *Blepharis ciliaris*, the cactus-like milkweed *Desmidorchis arabicus*, the slope shrubs *Iphiona scabra* and *Vernonia arabica*, and annuals like the erect but wispy *Gypsophila bellidifolia* and *Misopates orontium*, the diminutive, sheltering *Andrachne aspera* and *Nanorrhinum hastatum*, the sometimes gangling *Erodium neuradifolium* and *Geranium* species, and the dodder *Cuscuta planifora*.

"Rare" species require greater patience and effort. Most of them were not unexpected in WWNP, but they have been recorded only in very small numbers, many in remote locations. Some examples are the climbers *Ephedra foliata* and *Pentatropis nivalis*, the newly recognised *Launaea omanensis*, the spiny shrub *Astragalus fasciculifolius*, and the small grasses *Enneapogon desvauxii* and *Eragrostis ciliaris*.

"Exceptional" species may require luck as well as persistence, although several were recorded in an area frequented by the general public. Most were unexpected in WWNP and have been recorded only once or twice. They include the four introduced exotic species mentioned in Observation 1.1.1, none of which are likely to survive to maturity in WWNP. Other examples are the rare UAE-Oman endemic *Scrophularia imbricata*, *Tephrosia* cf. *uniflora*, the tiny, herbaceous *Asterolinon linum-stellatum*, otherwise known only from the high Musandam, and "indigenous exotics" such as the large, errant desert shrub *Leptadenia pyrotechnica*.

1.2. Comparison with the Ru'us al-Jibal range.
In order to provide context for the WWNP survey results, they can be compared with similar data for the adjacent Ru'us al-Jibal range, which has been the subject of relatively comprehensive floristic investigation (Feulner 2011). In terms of gross figures:

- 53 families are represented in WWNP versus 68 in the Ru'us al-Jibal (78%).
- 163 genera are represented in WWNP versus 239 genera in the Ru'us al-Jibal (68%).
- 202 native species are recorded from WWNP versus 338 from the Ru'us a-Jibal (60%).

1.2.1. Adjustment for the greater elevation of the Ru'us al-Jibal. The foregoing comparisons of aggregate numbers are not entirely fair, because the Ru'us al-Jibal is considerably higher than the mountains of WWNP and Shimayliyah generally, it features relatively extensive plateau areas at elevations from 500 to 1500 metres, and it is characterised by a distinctive higher elevation vegetation zone. More specifically, the Ru'us al-Jibal is home to 75 species that, within the UAE and Oman, are found only there. Of those 75 species, 56 are found only above *ca.* 700 metres (Feulner 2011 at Section 2, pp. 49-50 and Table 3).

A further adjustment should perhaps be made in the interest of a "fair" comparison, since the WWNP figures include records from the silted basin behind Wadi Wurayah dam, whereas the Ru'us al-Jibal figures exclude records from an extensive, low elevation, silty parkland called Sal al-'Ala, where a large number of widely distributed annuals (including several grasses) were collected, many of which are neither common in nor characteristic of mountain areas (Feulner 2011, Appendix at p. 98). That adjustment is not significant, however, since only one species was found in the Wadi Wurayah dam basin that was not found at other sites within WWNP (the wild mustard *Sinapis arvensis*).

If the Ru'us al-Jibal figures are adjusted by subtracting the 56 higher elevation species, and if the WWNP figures are reduced by the one species found only in the dam basin, the species totals remain disparate but the comparison is much closer: 201 for WWNP versus 282 for the Ru'us al-Jibal (71%). By this measure, the floristic diversity of WNPP is (in round numbers) at least 70% of that of the Ru'us al-Jibal at comparable elevations.

1.2.2. The distinctive geochemistry of the ultrabasic environment. The forgoing is not an unexpected result, for reasons briefly introduced earlier. Although the ophiolite mountains are relatively rich in surface water compared to the carbonate massif of the Ru'us al-Jibal, the distinctive geochemistry of the ophiolite environment poses special difficulties for plant life:

> "The weathering of ultrabasic rocks such as the ophiolite of the Hajar Mountains creates soils that generally have distinctive chemical characteristics. They are deficient in calcium and other essential nutrients, such as nitrogen and phosphorus; they are rich in magnesium, which interferes with the uptake of calcium; and they usually have high levels of heavy metals such as chromium, nickel and cobalt. The slow percolation of groundwater through ultrabasic rock in an arid climate also produces exceptionally alkaline groundwater, with pH as high as 11.9." [Feulner (2011) at Section 6.2, citations omitted.]

The ophiolite of the Hajar Mountains has generally been considered to exhibit low botanical diversity (e.g., Insall 1999), although Munton (1985) was judicious in accounting for his early observations (in the area northwest of the Jebel Akhdar), allowing that they might reflect in part the combination of drought (at the time of his observations) and relatively extensive human inhabitation of the area, with concomitant exploitation by agriculturalists and pastoralists.

When examined in detail, however, there exist certain floral differences between WWNP and the Ru'us al-Jibal which are not necessarily explained by ultrabasic geochemistry. In some cases alternative explanations suggest themselves; in other cases the reasons remain speculative. These are discussed briefly in Observation 1.2.4 below, and in more detail in Observation 9.

1.2.3. Family level comparisons.

- As noted above, the same three families (Poaceae, Asteraceae, and Fabaceae) hold the top three positions in the lists for both WWNP and the Ru'us al-Jibal, and six additional families (Boraginaceae, Brassicaceae, Caryophyllaceae, Euphorbiaceae, Lamiaceae and Scrophulariaceae) appear in the top dozen positions in both lists (Table 3).
- Grass species (Poaceae) are slightly over-represented in WWNP (as a proportion of total species) relative to the Ru'us al-Jibal. The number of grass species in WWNP is 67% of the number of grasses in the Ru'us al-Jibal, whereas the total number of WWNP species is only 60% of the Ru'us al-Jibal total (Table 3). Grass species represent 15% of the recorded flora of WWNP versus only 13% of the Ru'us al-Jibal flora. That comparison is unchanged if the Ru'us al-Jibal data is adjusted by subtracting the exclusively higher elevation species, as described above. The percentage of grass species in the flora as a whole is 17% for both the UAE and Oman, so from that perspective, grasses are slightly under-represented in both mountain areas.
- Most plant families other than grasses (Poaceae) are under-represented in WWNP, relative to the Ru'us al-Jibal, having only half or less the number of species. Some exceptions are noted in the following paragraphs.

- Asclepiadaceae is considerably over-represented in WWNP, having 7 species present, versus only 5 in the Ru'us al-Jibal. However, 2 Asclepiadaceae species are so far known in WWNP from only one or two specimens, and one of those species is considered exceptional.
- Scrophulariaceae is also over-represented in WNNP, having an equal number of species (10) in both WWNP and the Ru'us al-Jibal. However, three Scrophulariaceae species from WWNP have so far been found only in the buffer zone and another is known from only two specimens.
- Cyperaceae is greatly over-represented in WWNP, being only a minor family in the Ru'us al-Jibal and in the UAE and Oman lists. The relatively high count for Cyperaceae reflects the concentration of hygrophilous species at the Wadi Wurayah waterfall area.
- 3 species of Solanaceae were recorded in WWNP, but two are single historical records and the third is found only in the waterfall picnic area where introduction by human activity is possible. This contrasts with 3 species of Solanaceae that are occasional in the Ru'us al-Jibal.
- No Apiaceae spp. were recorded from WWNP, whereas at least 6 species are found in the Ru'us al-Jibal. At least three of the UAE representatives of this family, most of which are annuals, are restricted to the carbonate rocks of the Ru'us al-Jibal; the distribution of two other species, the perennials *Ducrosia anethifolia* and *Pycnocycla caespitosa*, suggests that they may preferentially colonise carbonate rocks and avoid ultrabasic rocks. Jongbloed (2003) says that the annual *Ammi majus* is "locally common and widespread in the Hajar Mountains" and maps it accordingly, but Karim & Fawzi (2007) give its habitat as "[c]ultivated places or roadsides" and El-Keblawy (2011) did not record it from Wadi Hiluw.
- Several families comprising primarily annual species (e.g., Geraniaceae, Plantaginaceae and Primulaceae) show little difference in species numbers between WWNP and the Ru'us al-Jibal.

1.2.4. Species level comparisons.

- Ru'us al-Jibal species not found in the Hajar Mountains. Of the 75 Ru'us al-Jibal species previously considered to be absent or nearly so in the Hajar Mountains (Feulner 2011, Table 3), five have in fact been found within WWNP. *Asterolinon linum-stellatum* and *Astragalus fasciculifolius* appear to be genuinely rare. *Bromus danthoniae* and *Gastridium phleoides* are grasses of higher elevations and could possibly be under-recorded in WWNP, where higher elevations are very rugged and access is difficult; *B. danthoniae* is distinctive, but *G. phleoides* is not. In contrast to prior understanding, however, *Geranium biuncinatum* appears to be the most common *Geranium* species in WWNP, although the several *Geranium* species can only be distinguished confidently when they are in seed.

- Hajar Mountain species not found in the Ru'us al-Jibal. Looked at from the opposite perspective, three dozen (36) species have been described as "[c]ommon Hajar Mountain species that are absent or very rare in the Ru'us al-Jibal" (Feulner 2011, Table 5). Possible explanations for those discrepancies include not only (i) ultrabasic geochemistry, but also (ii) differential hydrology between the karst environment of the Ru'us al-Jibal carbonates and the ophiolite of the Hajar Mountains (specifically, the absence of significant surface or near-surface water in the Ru'us al-Jibal to support hygrophilic species); (iii) edaphic differences, i.e., differences in the development and character of the soil and substrate; and (iv) regional biogeographical gradients.

  Of that subset of three dozen "common Hajar Mountain species that are absent or very rare in the Ru'us al-Jibal", 21 species are in fact common, locally common or at least occasional within WWNP. Most of these species can rightly be called characteristic of the Hajar Mountains:

Aizoon canariense
Arundo donax
Boerhavia elegans
Chrozophora oblongifolia
Cleome noeana
Cleome rupicola
Cometes surattensis
Convolvulus virgatus
Crotalaria aegyptiaca
Haplophyllum tuberculatum
Hibiscus micranthus
Iphiona scabra
Morettia parviflora
Nerium oleander
Physorrhynchus chamaerapistrum
Pulicaria glutinosa
Reseda aucheri
Saccharum griffithii
Taverniera cuneifolia
Tribulus terrestris
Trichodesma enetotrichum

Table 2A: Plant species of Wadi Wurayah National Park: An alphabetical list of species recorded within the area of WWNP

Key to Tables 2A, 2B, 2C and 2D

*	Endemic to UAE & Northern Oman.
=	Earlier name has been invalidated by synonymy or reclassification.
≈	Alternative species not distinguished here and treated as equivalent.
>	Earlier identification or nomenclature has been distinguished.
(1), (2)	Limited number of specimens observed (1, 2 or 3, as shown).
ex	Introduced exotic (non-native) species.
Abadilah	Recorded in Wadi Abadilah (WNPP buffer zone) only.
HQ	Recorded in Headquarters Wadi (WNPP buffer zone) only.
Siji	Recorded in upper Wadi Siji (WNPP buffer zone) only.
Zikt	Recorded in Wadi Zikt (within WNPP) only.
Zikt BZ	Recorded in Wadi Zikt (WNPP buffer zone) only.
[Name, mo/year]	Historical record, including source and date.
Single location	Two or more plants in close proximity (up to 10-20 meters apart).
Single locality	Two or more plants within a few tens of meters.

Species	Remarks	Family
Acacia ehrenbergiana HQ		Mimosaceae
Acacia tortilis		Mimosaceae
Adiantum capillus-veneris		Pteridaceae
Aerva javanica		Amaranthaceae
Aizoon canariense		Aizoaceae
Anagallis arvensis		Primulaceae
Anchusa aegyptiaca Siji (1)		Boraginaceae
Andrachne aspera		Euphorbiaceae
Anticharis glandulosa		Scrophulariaceae
Argyrolobeum roseum		Fabaceae
Aristida abnormis		Poaceae
Aristida adscensionis		Poaceae
Arnebia hispidissima		Boraginaceae
Arundo donax		Poaceae
Asphodelus tenuifolius		Liliaceae
Asterolinon linum-stellatum	Single location, W. Ghayl. Prior UAE records from Ru'us al-Jibal only.	Primulaceae
Astragalus fasciculifolius Zikt		Fabaceae
Blepharis ciliaris		Acanthaceae
Boerhavia elegans		Nyctaginaceae
Bolboschoenus maritimus		Cyperaceae
Brachypodium distachyum		Poaceae
Bromus danthoniae Siji (1)		Poaceae
Bromus madritensis Siji	[Curtis, 03/1998]	Poaceae
Callipeltis cucullaris Siji		Rubiaceae
Calotropis procera		Asclepiadaceae
Campanula erinus (2)	Includes [Curtis, 3/1998]	Campanulaceae

Species	Remarks	Family
Capparis spinosa		Capparaceae
Castellia tuberculosa (2)	Includes [Curtis, 03/1998]	Poaceae
Cenchrus ciliaris		Poaceae
Centaurium pulchellum (2)	Includes [Feulner, 03/1998]	Gentianaceae
Chaenorrhinum rubrifolium Siji		Scrophulariaceae
Cheilanthes acrostica Siji	= C. pteridioides [Curtis, 03/1998]	Pteridaceae
Chenopodium murale		Chenopodaceae
Chrozophora oblongifolia		Euphorbiaceae
Citrullus colocynthis		Cucurbitaceae
Citrullus lanatus[ex]	Cultivated watermelon. Two locations.	Cucurbitaceae
Cladium mariscus	Sole UAE location is W. Wurayah waterfall.	Cyperaceae
Cleome austroarabica		Capparaceae
Cleome noeana	> C. dolichostyla	Capparaceae
Cleome rupicola		Capparaceae
Cleome scaposa Abadilah	[Feulner, 10/2003]	Capparaceae
Cocculus pendulus		Menispermaceae
Cometes surattensis		Caryophyllaceae
Convolvulus glomeratus		Convolvulaceae
Convolvulus virgatus		Convolvulaceae
Corchorus depressus	Single location, Wadi Ghayl.	Tiliaceae
Crotolaria aegyptiaca		Fabaceae
Cucumis prophetarum		Cucurbitaceae
Cuscuta planifora		Convolvulaceae
Cymbopogon schoenanthus		Poaceae
Cynodon dactylon Siji		Poaceae
Cyperus rotundus		Cyperaceae
Cyperus conglomeratus		Cyperaceae
Desmidorchis arabicus*	= Caralluma arabica	Asclepiadaceae
Dianthus crinitus (2)	Single location, on a broad rubble slope in upper Dam Wadi.	Caryophyllaceae
Dicanthium foveolatum	Two locations, both peri-anthropic.	Poaceae
Digitaria nodosa		Poaceae
Diplotaxis harra		Sapindaceae
Dyerophytum indicum		Plumbaginaceae
Echinochloa crusgalli Siji	Single location in fallow field.	Poaceae
Echinops erinaceus		Asteraceae
Echiochilon persicus Siji (1)	[Feulner, 12/1995]	Boraginaceae
Enneapogon desvauxii (1)		Poaceae
Enneapogon persicum	Single locality.	Poaceae
Ephedra foliata (5)	= Ephedra ciliata	Ephedraceae
Epipactis veratrifolia		Orchidaceae
Eragrostis barrelieri HQ, Siji		Poaceae
Eragrostis cilianensis		Poaceae
Eragrostis ciliaris HQ		Poaceae

Species	Remarks	Family
Erodium neuradifolium		Geraniaceae
Euphorbia arabica		Euphorbiaceae
Euphorbia granulata		Euphorbiaceae
Euphorbia larica		Euphorbiaceae
Fagonia brugueri		Zygophyllaceae
Fagonia indica Siji, Zikt BZ (3)		Zygophyllaceae
Ficus cordata salicifolia		Moraceae
Ficus johannis		Moraceae
Ficus religiosa ex (1)	Seedling at W. Wurayah waterfall.	Moraceae
Filago desertorum		Asteraceae
Filago pyramidatum Siji		Asteraceae
Forsskaolea tenacissima		Urticaceae
Galium decaisnei	= G. setaceum	Rubiaceae
cf. Galium sp. Zikt (1)	[Feulner, 01/2012]	Rubiaceae
Gastridium phleoides Siji	[Curtis, 03/1998]	Poaceae
Geranium biuncinatum		Geraniaceae
Geranium trilophum		Geraniaceae
Glossonema varians (2)		Asclepiadaceae
Grewia erythraea		Tiliaceae
Gymnocarpos decandrus		Caryophyllaceae
Gypsophila bellidifolia		Caryophyllaceae
Haloxylon salicornicum Zikt BZ	Single location. [Feulner, 09/2012]	Chenopodaceae
Haplophyllum tuberculatum		Rutaceae
Helianthemum lippii		Cistaceae
Helichrysum glumaceum		Asteraceae
Heliotropium brevilimbe	= H. calcareum	Boraginaceae
Hibiscus micranthus		Malvaceae
Hippocrepis constricta		Fabaceae
Hyoscyamus muticus Abadilah (1)	[Feulner, 10/2003]	Solanaceae
Hyparrhenia hirta		Poaceae
Ifloga spicata		Asteraceae
Indigofera coerulea	Single location [Feulner, 01/2015] (recorded subsequent to final report)	Fabaceae
Iphiona scabra		Asteraceae
Lappula spinocarpos Siji		Boraginaceae
Launaea bornmuelleri	> L. spinosa	Asteraceae
Launaea capitata		Asteraceae
Launaea massauensis		Asteraceae
Launaea omanensis*		Asteraceae
Launaea procumbens (1)		Asteraceae
Lavandula subnuda		Lamiaceae
Leptadenia pyrotechnica (2)	Two perianthropic locations.	Asclepiadaceae
Leucas inflata		Lamiaceae

Species	Remarks	Family
Lindenbergia arabica*		Scrophulariaceae
Lindenbergia indica Zikt BZ (2)	= L. fruticosa. Single location. [Feulner, 01/2012]	Scrophulariaceae
Linum corymbulosum		Linaceae
Lotononis platycarpa		Fabaceae
Lotus schimperi (1)		Fabaceae
Lycium shawii (1)	[Feulner, 10/2003]	Solanaceae
Malva parviflora Zikt (1)	[Feulner, 01/2012]	Malvaceae
Mangifera indica ex (1)	Cultivated mango seedling in pond above waterfall. [Feulner,05/2008]	Anacardiaceae
Medicago laciniata Abadilah	Single location.	Fabaceae
Misopates orontium		Scrophulariaceae
Monsonia cf. heliotropioides (2)	Two perianthropic locations.	Geraniaceae
Morettia parviflora		Brassicaceae
Moringa peregrina		Moringaceae
Nanorrhinum elatinum Abadilah, Zikt (3)	> N. acerbianum (= Kickxia acerbiana)	Scrophulariaceae
Nanorrhinum hastatum	= Kickxia hastata	Scrophulariaceae
Nerium oleander		Apocynaceae
Notoceras bicorne Zikt (1)	[Feulner, 1/2012]	Brassicaceae
Ochradenus arabicus		Resedaceae
Ochradenus aucheri		Resedaceae
Oligomeris linifolia		Resedaceae
Onychium divaricatum		Pteridaceae
Ophioglossum polyphyllum	Single locality.	Ophioglossaceae
Orobanche cernua		Orobanchaceae
Papaver decaisnei	Single location(?) [Tourenq, 03/2006]	Papaveraceae
Paracaryum intermedium	Two locations.	Boraginaceae
Parietaria alsinifolia		Urticaceae
Paronychia arabica	WWNP records extend range shown in Jongbloed (2003).	Caryophyllaceae
Pennisetum divisum (3)		Poaceae
Pennisetum orientale Siji	[Curtis, 03/1998]	Poaceae
Pentanema divaricatum Zikt	[Feulner, 03/1997]	Asteraceae
Pentatropis nivalis (1)		Asclepiadaceae
Pergularia tomentosa		Asclepiadaceae
Periploca aphylla		Asclepiadaceae
Phagnalon schweinfurthii (2)	Single location, W. Ghayl.	Asteraceae
Phoenix dactylifera		Arecaceae
Physalis minima	Single location, W. Wurayah waterfall.	Solanaceae
Physorrhynchus chamaerapistrum		Brassicaceae
Plantago afra		Plantaginaceae
Plantago amplexicaulis		Plantaginaceae
Plantago ciliaris		Plantaginaceae
Plantago ovata		Plantaginaceae

Species	Remarks	Family
Plocama aucheri	= Gaillonia aucheri	Rubiaceae
Plocama hymenostephana	= Pseudogaillonia hymenostephana	Rubiaceae
Polycarpaea robbairea		Caryophyllaceae
Polygala erioptera		Polygalaceae
Prosopis cineraria	Three locations.	Mimosaceae
Pseudolotus makranicum		Fabaceae
Pteropyrum scoparium*		Polygonaceae
Pulicaria edmondsonii*	= Pulicaria nobilis	Asteraceae
Pulicaria glutinosa		Asteraceae
Reichardia tingitana		Asteraceae
Reseda aucheri		Resedaceae
Rhazya stricta Abadilah	Single location. [Feulner, 10/2003]	Apocynaceae
Rhynchosia minima Abadilah (1)	[Feulner, 10/2003]	Fabaceae
Rostraria pumila		Poaceae
Rumex limoniastrum* Zikt, Siji (2)		Polygonaceae
Rumex vesicarius		Polygonaceae
Saccharum griffithii	> S. ravennae	Poaceae
Saccharum kajkaiense	Single location above W. Wurayah waterfall is sole known East Coast site.	Poaceae
Salvia aegyptiaca		Lamiaceae
Salvia macilenta		Lamiaceae
Salvia macrosiphon	= S. spinosa	Lamiaceae
Satureja imbricata Siji, Zikt	[Curtis, 03/1998] [Feulner 01/2012]	Lamiaceae
Schoenus nigricans		Cyperaceae
Schweinfurthia imbricata* (2)		Scrophulariaceae
Schweinfurthia papilionacea Siji		Scrophulariaceae
Sclerocephalus arabicus Siji (1)	[Feulner, 03/1998]	Caryophyllaceae
Scrophularia deserti		Scrophulariaceae
Senecio breviflorus	> S. flavus	Asteraceae
Senna italica	= Cassia italica	Fabaceae
Silene austro-iranica		Caryophyllaceae
Sinapis arvensis (2)	Single location.	Brassicaceae
Sisymbrium erysimoides		Brassicaceae
Solanum lycopersicum ex (2)	= Lycopersicum esculentum (cultivated tomato). Single location, perianthropic. [Feulner, 05/2008]	Solanaceae
Sonchus oleraceus	Two perianthropic localities.	Asteraceae
Spergula fallax		Caryophyllaceae
Spergularia diandra Zikt (1)		Caryophyllaceae
Sporobolus spicatus	Single locality, W. Wurayah waterfall.	Poaceae
Stipa capensis		Poaceae
Stipagrostis hirtigluma		Poaceae
Sueda aegyptiaca (3)		Chenopodaceae

Species	Remarks	Family
Taverniera cuneifolia	= T. glabra	Fabaceae
Tephrosia apollinea	≈T. purpurea subsp. leptostachya	Fabaceae
Tephrosia cf. uniflora (3)	Two locations.	Fabaceae
Tetrapogon villosus Siji	Two locations.	Poaceae
Teucrium stocksianum (5)	Three locations.	Lamiaceae
Tribulus terrestris		Zygophyllaceae
Trichodesma enetotrichum		Boraginaceae
Tricholaena teneriffae		Poaceae
Typha domingensis		Poaceae
Vernonia arabica		Asteraceae
Viola cinerea		Violaceae
Zaleya pentandra HQ	Single locality.	Aizoaceae
Ziziphus spina-christi		Rhamnaceae
Zoegea purpurea		Asteraceae

Table 2B: WWNP species recorded to date only within the WWNP buffer zone (site shown in superscript)

Acacia ehrenbergiana HQ
Anchusa aegyptiaca Siji
Bromus danthoniae Siji
Callipeltis cucullaris Siji
Chaenorrhinum rubrifolium Siji
Cheilanthes acrostica Siji
Cleome scaposa Abadilah
Cynodon dactylon Siji
Echinochloa crusgalli Siji
Echiochilon persicum Siji
Eragrostis barrelieri HQ, Siji
Eragrostis ciliaris HQ
Fagonia indica Siji, Zikt BZ
Filago pyramidatum Siji
Gastridium phleoides Siji
Haloxylon salicornicum Zikt BZ
Hyoscyamus muticus Abadilah
Lappula spinocarpos Siji
Lindenbergia indica Zikt BZ
Medicago laciniata Abadilah
Pennisetum orientale Siji
Rhazya stricta Abadilah
Rhynchosia minima Abadilah
Schweinfurthia papilionacea Siji
Sclerocephalus arabicus Siji
Tetrapogon villosus Siji
Zaleya pentandra HQ

Table 2C: WWNP species known to date only from historical records

Species	Historical Record
Cheilanthes acrostica Siji	> C. pteridioides [Curtis, 03/1998]
Cleome scaposa Abadilah	[Feulner, 10/2003]
Echiochilon persicum Siji	[Feulner, 12/1995]
cf. Galium sp. Zikt	[Feulner, 01/2012]
Gastridium phleoides Siji	[Curtis, 03/1998]
Haloxylon salicornicum Zikt BZ	[Feulner, 09/2012]
Hyoscyamus muticus Abadilah	[Feulner, 10/2003]
Lindenbergia indica Zikt BZ	= L. fruticosa [Feulner, 01/2012]
Malva parviflora Zikt	[Feulner, 01/2012]
Mangifera indica ex	[Feulner, 05/2008]
Notoceras bicorne Zikt	[Feulner, 01/2012]
Papaver decaisnei	[Tourenq, 03/2006]
Pennisetum orientale Siji	[Curtis, 03/1998]
Pentanema divaricatum Zikt	[Feulner, 03/1997]
Rhazya stricta Abadilah	[Feulner, 10/2003]
Rhynchosia minima Abadilah	[Feulner, 10/2003]
Satureja imbricata Siji, Zikt	[Curtis, 03/1998] [Feulner, 01/2012]
Sclerocephalus arabicus Siji	[Feulner, 03/1998]
Solanum lycopersicum ex	[Feulner, 05/2008]

Table 2D: WWNP species found to date only within the Wadi Zikt watershed

Species	Remarks
Astragalus fasciculifolius Zikt	Mature shrubs limited to upper SW Branch
cf. Galium sp. Zikt	[Feulner, 01/2012]
Haloxylon salicornicum Zikt BZ	[Feulner, 09/2012]
Lindenbergia indica Zikt BZ	= L. fruticosa [Feulner, 01/2012]
Malva parviflora Zikt	[Feulner, 01/2012]
Notoceras bicorne Zikt	[Feulner, 01/2012]
Pentanema divaricatum Zikt	[Feulner, 03/1997]
Spergularia diandra Zikt	

Table 3: Comparison of plant families best represented (by number of species) in WWNP, the Ru'us al-Jibal, the UAE and Oman.

Wadi Wurayah National Park (202 spp.)		**Ru'us al-Jibal (Feulner 2011) (338 spp.)**	
Poaceae	30	Poaceae	45+
Asteraceae	20	Asteraceae	43
Fabaceae	13	Fabaceae	25
Caryophyllaceae	10	Brassicaceae	21
Scrophulariaceae	10	Caryophyllaceae	21
Asclepiadaceae	7	Boraginaceae	17
Boraginaceae	7	Lamiaceae	11
Lamiaceae	7	Euphorbiaceae	10
Brassicaceae	6	Scrophulariaceae	10
Capparaceae	5	Rubiaceae	8
Cyperaceae	5	Capparaceae	7
Euphorbiaceae	5	Apiaceae	6
Rubiaceae	5	Asclepiadaceae	5
Geraniaceae	4	Geraniaceae	5
Plantaginaceae	4	Plantaginaceae	5
Resedaceae	4		
UAE (Jongbloed *et al.* 2000) (*ca.* 675 spp.)		**Oman (Ghazanfar 1992b) (1174 spp.)**	
Poaceae	114	Poaceae	201
Asteraceae	84	Asteraceae	98
Fabaceae	73	Fabaceae	81
Chenopodiaceae	39	Euphorbiaceae	39
Brassicaceae	37	Scrophulariaceae	38
Boraginaceae	30	Caryophyllaceae	37
Caryophyllaceae	27	Boraginaceae	37
Euphorbiaceae	27	Lamiaceae	35
Zygophyllaceae	19	Acanthaceae	31
Convolvulaceae	17	Brassicaceae	31
Lamiaceae	17	Malvaceae	31

On the other hand, fifteen (15) of the "common Hajar Mountain species . . ." are absent or very rare in WWNP as well as the Ru'us al-Jibal. This signals the importance of factors other than carbonate versus ultrabasic geochemistry alone, and highlights the existence of biogeographical differentiation *within* the Hajar Mountains. In fact, five of the "common" species that are absent or rare in both the Ru'us al-Jibal and in WWNP, are absent in WWNP because it is situated beyond the northern extent of their regional biogeographic range. The other ten (10) species require more individualised explanations.

Observation 9 below deals more generally with plant biogeography *within* the ophiolite rocks of the Hajar Mountains, and specifically with the phenomenon of "common" species that are absent or very rare in WNPP, whether or not they are also present in the Ru'us al-Jibal.

1.3. Comparison with Wadi Hiluw – a gabbro environment in the Hajar Mountains.

A further instructive comparison of the WWNP survey results can be made with the Wadi Hiluw Protected Area in Sharjah Emirate. Wadi Hiluw (a.k.a. Wadi Helo) drains a large area of the mountains of the East Coast hinterland, some 50 km south of WWNP. The bedrock of the Wadi Hiluw watershed consists almost entirely of gabbro, which has a chemical composition essentially the same as basalt, but is more coarsely crystalline. Compared to harzburgite, gabbro has a higher content of silica (SiO_2) and a more normal geochemistry. In geological terms it is considered a "basic" rock, in contrast to the "ultrabasic" harzburgite.

El-Keblawy (2011) is a report of a survey of the flora of Wadi Hiluw. That survey recorded a total of 216 plant species in 35 families, of which 147 species were said to have been recorded in natural habitats, versus the balance of 69 species which were recorded only in "ruined [abandoned] and cultivated farms". It is frustrating for purposes of a precise comparison that the recorded species are not actually listed and categorised in full in the report, and although the photographic Appendix appears to be largely complete, it omits at least a few species mentioned in the text and tables. However, the photographs are in most cases very good and include multiple views in support of the species identifications. In addition, the photographic Appendix includes a number of rare species centred on the highlands to the north of Wadi Hiluw, indicating that the field work was diligently conducted. The Wadi Hiluw report is therefore taken here as the starting point for a rough comparison of floral diversity. (However, see also the note at the end of this Section, which discusses some important limitations of that report.*)

For the purpose of a comparison with WWNP, the Wadi Hiluw report's stated total of 147 species recorded from natural areas sets a baseline. Most of the identifications appear from the published photographs to be sound; a few are considered likely to be erroneous, but without affecting the total number of species. However, six species in the photo Appendix appear to be repeated under different labels (two are instances of species that have in fact been synonymised), leading to a small overcount; the adjusted total would be 141 species.

To that adjusted total must be added a further 11 species recorded by the present author in the course of field excursions over many years throughout natural areas of Wadi Hiluw, plus two congeners depicted but not separately identified in the photographic Appendix. The resulting total of 154 species is still substantially lower than the total of 202 native species recorded within WWNP (76%). That comparison is significant because it casts the seed of doubt on the conventional wisdom that the ultrabasic environment is characterised by reduced floral diversity.

The gap between the WWNP and Wadi Hiluw survey totals would be narrowed if, as is likely, some of the 69 Wadi Hiluw species said to have been recorded only from ruined or cultivated farms prove to be species that can be found in natural areas as well. Unfortunately the Wadi Hiluw report does not include data on the environment of collection for all species, but only for 133 species considered "common" in the UAE (El-Keblawy 2011, Table 6). The basis for designating those species as "common" is not specified but, from other comments in the text, it was probably derived from the categorisations in Jongbloed (2003) and Karim & Fawzi (2007).

A measure of possible skewing created by differences in survey coverage, methodology and timing is illustrated by consideration of the grass species reported from Wadi Hiluw. Of the 30 grass species depicted in the photographic Appendix to the Wadi Hiluw report, 16 are species not listed among the 30 grasses recorded in WWNP. At least 7 or 8 of those 16 are species typically associated with cultivation (which is essentially absent within WWNP) and at least 2 others may represent alternative identifications of congeners recorded from WWNP. Two are rare high elevation species. The Wadi Hiluw report does not indicate when or in what season(s) the underlying field work was conducted, so it is difficult to assess the significance of negative records, i.e., species not recorded, especially small annuals and grasses.

From the data tabulated in the Wadi Hiluw report, it is possible to estimate that at least 8-10 "farm" species are likely to be found in natural environments in Wadi Hiluw (e.g., widespread mountain grasses such as *Rostraria pumila* and *Hyparrhenia hirta* and annuals such as *Launaea capitata* and *Polygala erioptera*). Another 8-10 species could potentially be found in natural environments in isolated circumstances (as some of them are, within WWNP). In addition, at least a few species not yet recorded are

likely to be present, e.g., *Misopates orontium* and *Centaureum pulchellum*, both known from nearby Wadi Mayy. So on the basis of present knowledge, the total for natural environments in Wadi Hiluw could reasonably be *ca.* 175 species.

No comparable adjustment needs to be made for "farms" within WWNP, where only a single small agricultural field exists, in the buffer zone in upper Wadi Siji. That field was fallow when visited in March 2013 and March 2014 but it produced the sole WWNP records of *Cynodon dactylon* and *Echinochloa crusgalli*. The Adder's tongue fern *Ophioglossum polyphyllum* is the only other WWNP species that is suspected of association with former human cultivation. All survey records of *O. polyphyllum* were from a single locality, centred atop a thick gravel terrace where a small, shallow gulley appears to have been serially dammed for very localised agriculture, evidently well before the modern era.

It could be argued that a proper comparison of "natural areas" should also exclude species found in WWNP only in anthropogenic areas such as the silted basin and wadi behind Wadi Wurayah dam, or in synanthropic areas such as the picnicking area below the Wadi Wurayah waterfall. Only one species has been recorded exclusively from the silt accumulations behind the dam (the wild mustard *Sinapis arvensis*); exclusion of the waterfall picnic area would reduce the WWNP totals by a further six species (*Launaea procumbens*, *Lotus schimperi*, *Physalis minima*, *Sonchus oleraceus*, *Schweinfurthia imbricata* and *Sporobolus spicatus*). However, exclusion of the latter might require parallel exclusion of postulated exceptional occurrences in Wadi Hiluw.

All of the above potential adjustments taken together would still leave a quantitative gap of *ca.* 8-12% in favour of WWNP, so that even a fairly optimistic forecast for future flora records from Wadi Hiluw would result in no more than rough parity with WWNP for natural environments.

[**NB: Notwithstanding the evidently conscientious collection and compilation of floristic data by the Wadi Hiluw survey, it is imperative to caution that many of the conclusory judgments contained in the Wadi Hiluw report are seriously flawed and should not be relied on either as factually accurate information or as well-informed or appropriate guidance for future environmental management. This includes much of what appears in the "Executive Summary" and "Results" sections, and most of what is presented as "Conclusions and Practical Recommendations".*

Such a blanket criticism demands a measure of elaboration. The fundamental problem is that most of the conclusions and recommendations complained of go well beyond the information gathered by the Wadi Hiluw survey itself, and that, in formulating them, the report author, in default of personal experience with the UAE's mountain flora outside of Wadi Hiluw, has placed poorly-informed, highly selective and idiosyncratic reliance on information contained in (or sometimes erroneously inferred from) the several available and otherwise authoritative general references.]

Fig. 1.1. A bend in upper Wadi Zikt, showing the relationship of various environments typical of WWNP: the wadi bed, wadi bank, wadi wall, gravel terrace (multiple levels and different degrees of rock varnish are seen here), and stony and rocky slopes.

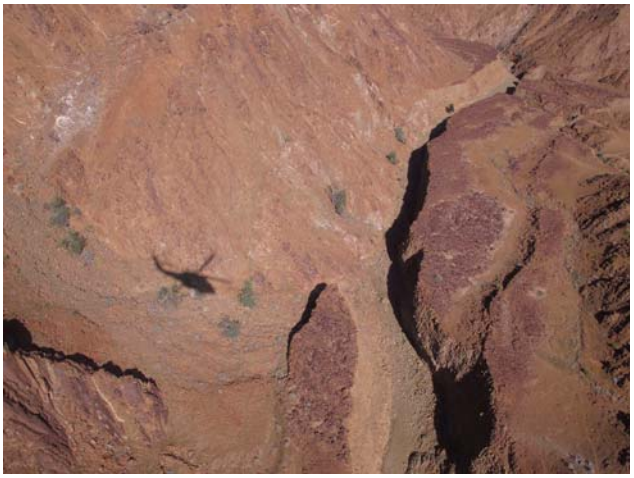


Fig. 1.2. A nearby area of upper Wadi Zikt, seen from directly overhead.

Fig. 1.3. An aerial view ESE from over the northern part of the Wadi Wurayah watershed, looking towards Bidiyah and the Gulf of Oman.

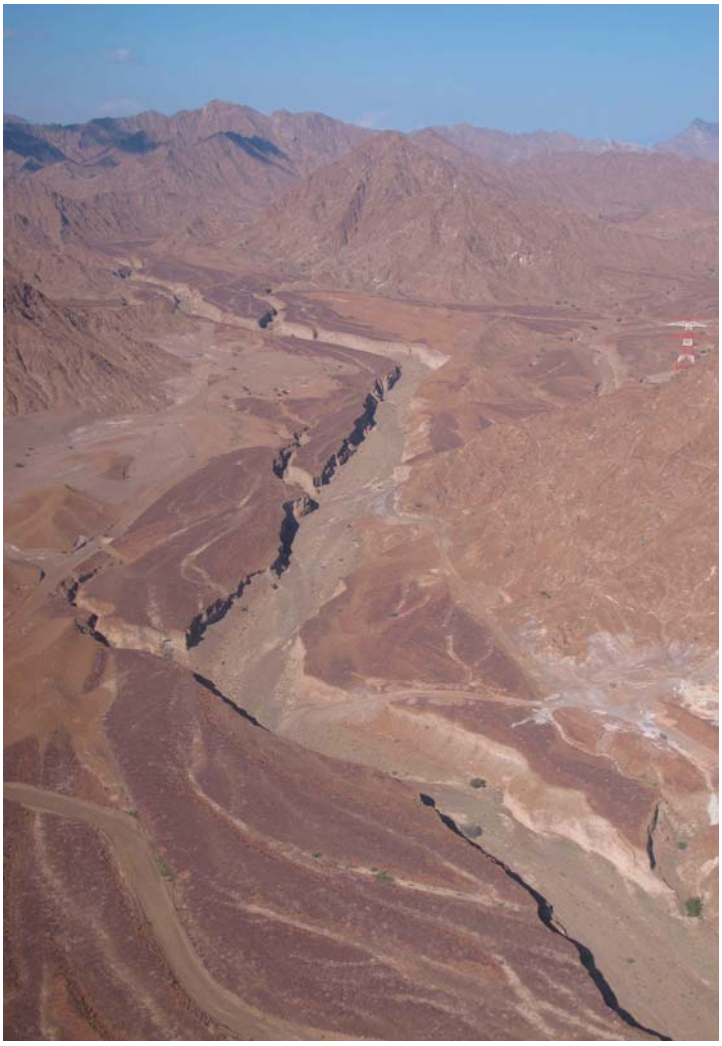


Fig. 1.4. An aerial view of lower Wadi Ghayl, the lowest major tributary of Wadi Wurayah.

Fig. 1.5. A view of the extensive gravel plains in the north-east of the Wadi Wurayah watershed.

Fig. 1.6. The rounded boulders on this low wadi bank in mid-Wadi Ghayl provide shelter for many dwarf shrubs and small annual plants.

Fig. 1.7. A gentle third-order tributary in the south-east of the Wadi Zikt watershed. Many larger shrubs are localised on the lower wadi bank.

Fig. 1.8. A third-order tributary of Wadi Ghayl, seen in March 2014, after two consecutive winters of relatively heavy rainfall. Many large shrubs line the wadi. The apparent yellow "flowers" on the shrub at the right are the winged fruits of *Dodonaea viscosa*.

Fig. 1.9. The mixed-size rubble of terraces and pediments along wadi banks is a favourable environment for many trees, shrubs and annual plants alike.

Fig. 1.10. "Green Wadi", a minor tributary of lower Wadi Wurayah, abloom in early January 2013, following December rain.

Fig. 1.11. Even in a rocky gorge, shrubs cluster on a wadi bank of coarse rubble at the base of a cliff.

Fig. 1.12. A mountain fig *Ficus johannis* in upper wadi Ghalil al-Haban, a fourth-order tributary.

Fig. 1.13. *Moringa peregrina* trees in a scree gulley in upper Wadi Zikt.

Fig. 1.14. A grove of common wadi grass, *Saccharum griffithii*, in mid-Wadi Wurayah (a.k.a. Wadi Murtaqam).

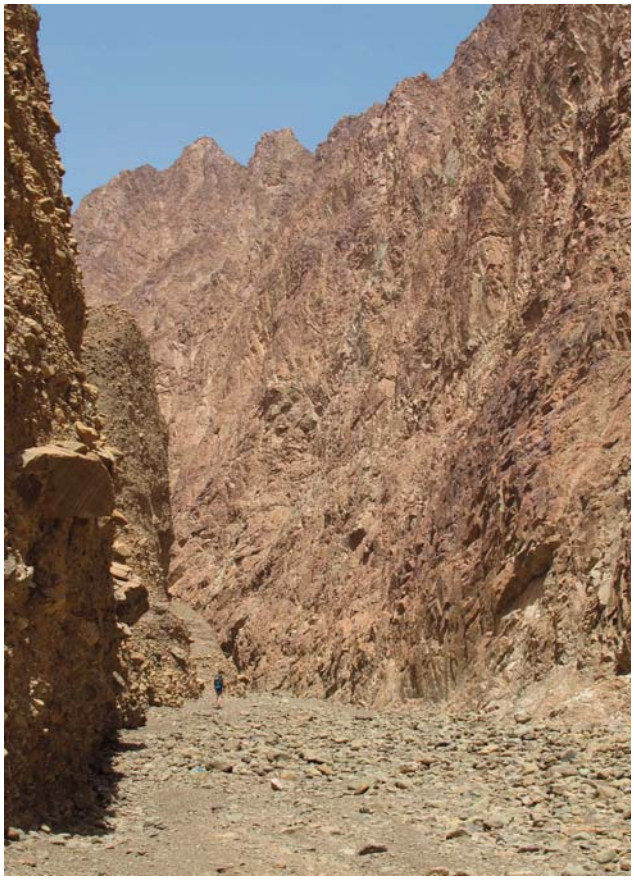


Fig. 1.15. A barren gorge in mid-Wadi Wurayah (a.k.a. Wadi Murtaqam).

Fig. 1.16. The rocky gorge and bed of a short, steep, third-order tributary of mid-Wadi Wurayah (a.k.a. Wadi Murtaqam). Little plant life can survive in this environment of occasional very high energy stream flow.

Fig. 1.17. Wadi Wurayah in flood at the popular waterfall area following an hour-long shower in mid-December 2012. (Photo by Jacky Judas)

Fig. 1.18. In wet years, surface water can be found for more than a kilometre above the Wadi Wurayah waterfall. The profuse growth of tall reeds (*Arundo donax*) is a serious impediment to exploration of this area.

Fig. 1.19. This terrace not far above the Wadi Wurayah waterfall still shows the remains of a series of small cultivated plots along a gulley draining it.

Fig. 1.20. The gulleys draining this long terrace above mid-Wadi Wurayah (a.k.a. Wadi Murtaqam) were once dammed to create multiple tiers of narrow fields.

Fig. 1.21. A terrace in dunite in lower Wadi Wurayah in winter, after recent rain. The predominant ground cover consists of *Tribulus terrestris* and *Asphodelus tenuifolius*.

Fig. 1.22. Dwarf shrubs concentrated in a shallow gulley beside the terrace shown in Fig. 1.21.

Fig. 1.23. *Euphorbia larica* dominates a gentle slope in dunite, adjacent to the terrace seen in Figs. 1.21 and 1.22.

Fig. 1.24.The same terrace shown in Figs. 1.21 and 1.22, seen here in late summer.

Fig. 1.25. After heavy rains, a lake may extend for up to 2 kilometres above Wadi Wurayah dam. The silt deposited behind the dam can support species not found elsewhere within WWNP.

Fig. 1.26. The author at the “White Dike”, a granitic intrusion above Dam Wadi, a high elevation site where rare species were encountered. (Photo by Maral K. Shuriqi)

Fig. 1.27. A large granitic dike cuts the harzburgite bedrock on the watershed between Wadi Wurayah and Wadi Zikt.

Fig. 1.28. A summertime view into upper Wadi Ghayl from a pass in the Nimriyah area of Wadi Zikt.

Fig. 1.29. *Acacia ehrenbergiana* at the WWNP headquarters area, now fenced but still subject to grazing by domestic goats from the neighbouring community. This area was home to four species not seen elsewhere in WWNP.

Fig. 1.30. War of the Worlds: Electricity pylons on the march along the mountain front in Wadi Zikt. The profile of the Ru'us al-Jibal (the mountains of the Musandam peninsula) is seen in the distance.

2. All eight of the UAE's mountain endemics are found in WWNP, including one endemic newly recorded by the baseline survey.

The UAE has no nationally endemic plant species, but eight species considered endemic to the mountains of the UAE and Northern Oman have been recorded within the UAE. All of those species are found in WWNP. One was recognised in the UAE for the first time during the course of the baseline survey:

- *Desmidorchis arabicus* (formerly *Caralluma arabica*) (Asclepiadaceae) (Fig. 2.1): a cactus-like succulent milkweed that is widespread but seldom encountered, probably because it favours rocky slopes that are difficult to access. It was recorded at numerous sites throughout WWNP.
- *Echinops erinaceus* (Asteraceae) (Fig. 2.2): A tall, spiny thistle, locally common on rubble and scree. This species is listed in Jongbloed (2003) only as *Echinops* sp. Feulner (2011) updated the nomenclature based on information from N. Kilian (*pers. comm.*).
- *Launaea omanensis* (Asteraceae) (Fig. 2.3): A semi-erect daisy with rubbery, leafless, greyish blue-green stems spreading from a basal rosette of thin, dissected and finely toothed leaves. The baseline survey produced the first record of this plant from the UAE. Single specimens have been found at four widespread and varied sites within WWNP. It has also been recorded subsequently from a rocky ridge on the slopes of Jebel Qitab in Fujairah Emirate, southwest of Fujairah city. The UAE records were identified, from photographs, by Dr. Norbert Kilian of the Botanic Garden and Botanical Museum Berlin-Dahlem, who first distinguished and named the species in 1997.
- *Lindenbergia arabica* (Scrophulariaceae) (Fig. 2.4): Usually a sparse, erect, opposite-leafed shrub, typically found on the vertical wadi walls of coarse gravel terraces; rare in WWNP.
- *Pteropyrum scoparium* (Polygonaceae) (Fig. 2.5): A medium-sized woody shrub with worm-like leaves, occasional along wadi banks and adjacent slopes; reportedly very similar to *P. aucheri* of Iran, Pakistan and Afghanistan.
- *Pulicaria edmondsonii* (Asteraceae) (Fig. 2.6): A slope-dwelling dwarf shrub that is locally common along gulleys at elevations above ca. 400 metres. It is also locally common in the Ru'us al-Jibal but uncommon in the mountains to the south of WWNP.
- *Rumex limoniastrum* (Polygonaceae) (Fig. 2.7): An erect to semi-pendant small shrub with fleshy, yellow-green, pointed oval leaves, resembling a caper plant but without spines, typically found on ledges, walls or other sites protected from browsing; widespread but very rare. After its collection by Aucher-Eloy in the Jebel Akhdar in 1837, it was not recorded again until the 1990s, when it was photographed at several sites in the UAE and northernmost Oman. Two specimens are known within WWNP. The first was a historical record from upper Wadi Siji, in the WWNP buffer zone, but in the course of the survey a specimen was found in upper Wadi Zikt, anomalously situated in the gravel wadi bed.
- *Schweinfurthia imbricata* (Scrophulariaceae) (Fig. 2.8): A prostrate, spreading annual with round, dark green, overlapping leaves. A rare and limited range species, it has been found mostly on gravel in the areas to the north and south of the Hatta road. It was not expected in WWNP, where two specimens have now been found, one in silt behind the Wadi Wurayah dam and one on gravel along the distal portion of the surface water outflow below the Wadi Wurayah waterfall. These are the northernmost UAE records, *ca*. 25 km from the closest other record, near Siji.

Fig. 2.1. *Desmidorchis arabicus* Asclepiadaceae)

Fig. 2.2. *Echinops erinaceus* (Asteraceae)

Fig. 2.3. *Launaea omanensis* (Asteraceae)

Fig. 2.4. *Lindenbergia arabica* (Scrophulariaceae)

Fig. 2.5. *Pteropyrum scoparium* (Polygonaceae)

Fig. 2.6. *Pulicaria edmondsonii* (Asteraceae)

Fig. 2.7. *Rumex limoniastrum* (Polygonaceae)

Fig. 2.8. *Schweinfurthia imbricata* (Scrophulariaceae)

3. WWNP is an important site for many rare species. For some, it is one of the only UAE sites.

WNPP is an important site, and in some cases one of the only known UAE sites, for a number of rare or otherwise noteworthy UAE plant species. A few of those are associated with the mesic environment of the permanent waterfall. The following list is indicative, not exhaustive.

- *Asterolinon linum-stellatum* (Primulaceae) (Fig. 3.1): The Wadi Ghayl branch of Wadi Wurayah is the only known UAE site outside the Ru'us al-Jibal for this delicate annual herb. It is, however, easily overlooked or conflated with *Anagallis arvensis*.
- *Bromus danthoniae* (Poaceae) (Fig. 3.2): This coarse-headed grass, apparently limited to high elevations, has previously been recorded in the UAE only from the Ru'us al-Jibal. It was found on a ridgetop in the southwest of WWNP.
- *Castellia tuberculosa* (Poaceae) (Fig. 3.3): The survey produced a photo record of this species from Wadi Ghayl. It was previously known in the UAE only from a single collection in upper Wadi Siji, within the WWNP buffer zone. A number of specimens have subsequently been recorded from the bed of a major ravine on the slopes of Jebel Qitab, southwest of Fujairah city.
- *Cladium mariscus* (Cyperaceae) (Fig. 3.4): The Wadi Wurayah waterfall area is the only known UAE site for this large, water-loving sedge. It is found in small bedrock pools at the base of the permanent waterfall, where it was first recorded in 2009 by Valerie Chalmers, Vice Chairman and Plant Recorder of the Dubai Natural History Group. When not in seed, it is difficult to distinguish from the other large hygrophilous monocots present.
- *Dianthus crinitus* (Caryophyllaceae): This is a Palearctic species and in the UAE and Northern Oman it is generally restricted to higher elevations. It is locally common in the Ru'us al-Jibal above 1000 metres; to the south, it is rare but has been found in the Jebel Akhdar and the Eastern Hajar Mountains above 1200 metres. The WWNP record (*ca.* 550 metres) is anomalously low, although Jongbloed (2003) mentions records from Masafi and the hills near Dibba. This species has one of the largest flowers of any UAE mountain plant.
- *Digitaria nodosa* (Poaceae) (Fig. 3.5): One of many similar congeners, this grass species has so far been recorded in the UAE only from Wadi Wurayah and Wadi Hiluw (El-Keblawi 2011). See also the discussion in Observation 11 below and the Checklist.
- *Enneapogon persicus* (Poaceae) (Fig. 3.6): This tall, silvery-green grass has been recorded in the UAE only rarely, from scattered locations in the Ru'us al-Jibal (Feulner 2011), from Khor Fakkan (Jongbloed 2003) and from cultivation in Wadi Hiluw (El-Keblawy 2011).
- *Epipactis veratrifolia* (Orchidaceae) (Fig. 3.7): The UAE's only orchid depends on water from seeps. Although the orchid is rare within WWNP, Wadi Wurayah has more permanent water than other UAE wadis, making it important as a potential refuge for this species.
- *Filago pyramidatum* (Asteraceae) (Fig. 3.8): This diminutive species is possibly under-reported due to its similarity to the more common, prostrate *F. desertorum*. It was found in WWNP in the gravel wadi bed of upper Wadi Siji.

Fig. 3.1 *Asterolinon linum-stellatum*, previously known in the UAE only from the Ru'us al-Jibal (the mountains of the Musandam peninsula).

- *Geranium biuncinatum* (Geraniaceae) (Fig. 3.9): Previously considered rare, this proved to be the prevailing *Geranium* species in WWNP. See also the discussion of *Geranium* spp. in Observation 11 below.
- *Geranium trilophum* (Geraniaceae) (Fig. 3.10): Distinguishable by its fruits and seeds, this *Geranium* species was also found in WWNP. See also the discussion of *Geranium* spp. in Observation 11 below.
- *Nanorrhinum elatinum* (Scrophulariaceae) (Fig. 3.11): A straggling species which apparently favours damp and/or shaded places. Four of the very few UAE records are from WWNP. This plant was originally identified by the author as *N. acerbianum*, based on Jongbloed (2003), but it is believed to be identical with the plant subsequently determined from Wadi Wurayah as *Kickxia elatine* (now *N. elatinum*) by Shahid and Rao (2015). The latter determination is supported by reference to Boulos (2002).
- *Ophioglossum polyphyllum* (Ophioglossaceae) (Fig. 3.12): An edible fern, the Adder's Tongue, that is threatened in its coastal habitat in the UAE, but that can also be found in silt accumulations in the mountains (Jongbloed 2003). The WWNP record may be related to ancient cultivation.
- *Papaver decaisnei* (Papaveraceae) (Fig. 3.13): A red poppy, most commonly found in the high Ru'us al-Jibal.
- *Rumex limoniastrum* (Polygonaceae): A rare UAE/Oman endemic. See discussion under Observation 2 above.
- *Saccharum kajkaiense* (Poaceae) (Fig. 3.14): The waterfall area of Wadi Wurayah is the only known East Coast site (and the northernmost Hajar Mountain site) for this cryptic wadi grass, rare in the UAE, which closely resembles the much more common *S. griffithii* (Feulner & Karki 2009, but NB: *S. griffithii* is discussed therein as *S. ravennae*).
- *Schweinfurthia imbricata* (Scrophulariaceae): An uncommon UAE/Oman endemic. See discussion under Observation 2 above.
- *Tephrosia* cf. *uniflora* (Fabaceae) (Fig. 3.15): Only a couple of earlier UAE records are known for this smaller and more delicate look-alike of the common *Tephrosia apollinea*.

Fig. 3.2 *Bromus danthoniae*, previously known only from scarce records in the Ru'us al-Jibal.

Fig. 3.3 *Castellia tuberculosa*. This erect grass appears to grow best in the bed of stony wadis.

Fig. 3.4 *Cladium mariscus*. The small, rocky pools at the base of the Wadi Wurayah waterfall are the only known UAE site for this tall reed.

Fig. 3.5 *Digitaria nodosa*. To date, the only UAE records of this conspicuous grass are from Wadi Wurayah and Wadi Hiluw, although it is likely to be more widespread.

Fig. 3.6 *Enneapogon persicus*. Several specimens of this distinctive grass are known from a single rocky gulley in Wadi Wurayah.

Fig. 3.7 *Epipactis veratrifolia*, the UAE's only orchid, a helleborine.

Fig. 3.8 *Filago pyramidatum*, distinguished from the more common *F. desertorum* by its erect habit and branched stems.

Fig. 3.9 *Geranium biuncinatum*, the predominant *Geranium* species in WWNP.

Fig. 3.10 *Geranium trilophum*, another *Geranium* species found in WWNP, distinguished by its fruits and seeds.

Fig. 3.11 *Nanorrhimum elatinum*. A synonym of *Kickxia elatina*, *N. elatinum* is probably the correct identification of what had previously been considered *N. acerbianum*.

Fig. 3.12 *Ophioglossum polyphyllum*. This elusive fern may be indicative of former cultivation.

Fig. 3.13 *Papaver* cf. *decaisnei*, a rare annual, one of the few red-flowering species in the UAE.

Fig. 3.14 *Saccharum kajkaiense*. In the UAE, Wadi Wurayah is the only known East Coast site for this species of wadi grass.

Fig. 3.15 *Tephrosia* cf. *uniflora*, easily overlooked among the more common *Tephrosia* species found in the UAE.

4. A list of the most biodiverse environments within WWNP includes both wild and synanthropic habitats.

A qualitative assessment of the most biodiverse habitats includes the following:

- Third-order tributary wadis with a low to moderate gradient. These wadis typically feature a close association of diverse small-scale habitats, which facilitates overall biodiversity, and they are not swept clean by flood waters to the same extent as lower order streams. Examples include Wadi Dhahir (a.k.a Green Wadi), about a kilometre below the Wadi Wurayah waterfall; the Blue Water (*May'a-t-al-Azraq*) Fork of Wadi Ghayl; and the Ghalil al-Haban Fork of upper Wadi Wurayah (a.k.a. Wadi Murtaqam).
  Among the species that were noticeably more common in these environments are: *Convolvulus glomeratus*, *Dodonaea viscosa*, *Lavandula subnuda*, *Leucas inflata*, *Galium decaisnei*, *Parietaria alsinifolia*, *Plocama hymenostephana*, *Pulicaria edmondsonii*, *Salvia macilenta*, and *Taverniera cuneifolia*.
  The middle reaches of Wadi Ghayl and its tributaries were especially noteworthy in terms of plant species diversity. That is probably due mostly to their geographic circumstances. Wadi Ghayl is the lowest of the major tributaries of the Wadi Wurayah watershed, and in addition, from its junction with Wadi Wurayah, it initially trends north for several kilometres, through foothills and gravel plains, before turning west into higher peaks. Thus, in its middle reaches it flows through somewhat gentler (but still highly varied) mountain terrain than the steeper upper tributaries, effectively behaving like a higher order stream, with corresponding opportunities for greater numbers of species.
  The Powerline Fork of Wadi Ghayl is a special case, having a very shallow gradient and flowing for several kilometres through low, rolling terraces and very low hills. Two species all but absent elsewhere in WWNP were found there in small numbers: *Pergularia tomentosa*

(Asclepiadaceae), a ruderal milkweed shrub, and *Teucrium stocksianum* (Lamiaceae), an edible aromatic species found elsewhere in the Hajar Mountains mostly at higher elevations but present in the Powerline Fork at low elevation beside shallow wadis in an area subject to browsing by goats and sheep. Also found there is the newly recognised UAE/Oman endemic *Launaea omanensis*.

- North-facing rubble slopes, shaded by a cliff. These provide a relatively mesic environment for plant life, especially annuals. Among the species associated with this environment are: *Anagallis arvensis*, *Asterolinon linum-stellatum*, *Ephedra foliata*, *Erodium neuradifolium*, *Forsskaolea tenacissima*, *Geranium biuncinatum*, *Geranium trilophum* and *Sisymbrium erysimoides*.
- The Wadi Wurayah dam basin. In the gravel wadi above the Wadi Wurayah dam, alluvial silt has accumulated in various places and to varying thicknesses for *ca.* 2 kilometres upstream, as a result of intermittent flooding. The Wadi Wurayah dam is a man-made feature but similar silt accumulations can be created naturally, e.g., by landslides (Feulner 2004). Among the plant species recorded in the silty alluvium, but only seldom recorded elsewhere within WWNP, are: *Chrozophora oblongifolia*, *Citrullus colicynthis*, *Cleome noeana*, *Cyperus conglomeratus*, *Monsonia* cf. *heliotropioides*, *Pennisetum divisum* and *Spergula fallax*. One species, *Sinapis arvensis* (wild mustard), was found only in this habitat (Fig. 4.7), and one of the two specimens of each of *Schweinfurthia imbricata* (Fig. 2.8) and *Tephrosia* cf. *uniflora* (Fig. 3.15) were also found there. There is a price to be paid, however, by plants that seek out the alluvial silt, and that is the threat of inundation or burial by subsequent floods. An exceptional flood in mid-March 2014 filled the basin and wadi behind the dam to within *ca.* 250 metres of the lower road crossing, wiping out all of the pre-existing basin vegetation and leaving a veneer of clean silt over a much greater area than previously observed.
- The outflow pools and rivulet at the base of the Wadi Wurayah waterfall, an area that has been heavily used by picnickers. A number of species were recorded here that have not been found elsewhere within WWNP. They represent a mix of water-loving and synanthropic species, plus opportunistic specimens of mountain species not typically found in such an environment (see also Observation 14 below). Among the rare, limited range and restricted habitat species and indigenous exotics that have been found there are:
Adiantum capillus-veneris, *Bolboschoenus maritimus*, *Campanula erinus*, *Centaurium pulchellum*, *Cladium mariscus*, *Citrullus lanatus* (watermelon), *Cyperus rotundus*, *Epipactis veratrifolia*, *Euphorbia granulata*, *Filago desertorum*, *Launaea procumbens*, *Lotus schimperi*, *Solanum lycopersicum* (tomato), *Ochradenus arabicus*, *Parietaria alsinifolia*, *Physalis minima*, *Sonchus oleraceus*, *Spergula fallax*, *Sporobolus spicatus* and *Typha domingensis*.
All environments within the main wadis are subject to significant disruption and reorganisation by flash floods, but this area at the base of the falls is particularly vulnerable. During a visit made on 4 November 2014, several days after heavy rain, no more than a third of the above listed species could be found. The apparent absentees included *C. erinus*, *C. pulchellum*, *C. mariscus* (a surprising absence for such a large species), *C. lanatus*, *C. rotundus*, *E. veratrifolia*, *E. granulata*, *F. desertorum*, *L. procumbens*, *L. schimperi*, *S. lycopersicum*, *O. arabicus*, *P. alsinifolia*, *S. oleraceus*, *S. fallax*, and *S. spicatus*. On the other hand, the tall reed *Arundo donax* had extended its dominion below the falls, both immediately below the waterfall pool and along the outflow downstream from the pipeline area. An interesting question is whether closure of the park to the general public (since mid-January 2014), may have eliminated some of the disruption (and inadvertent introductions) that allowed some of the foregoing opportunistic species to establish themselves. Several, however, are annual species that would not necessarily have been expected to persist into the fall season.
- The parking area on the gravel terrace at the end of the paved road. *Aristida abnormis*, *Cyperus conglomeratus*, *Dichanthium foveolatum*, *Galium decaisnei*, *Gymnocarpos decandrus* and *Monsonia* cf. *heliotropioides* were all recorded on the waste ground and gravel terrace adjacent to the parking area. All are native UAE species and *A. abnormis*, *G. decaisnei* and *G. decandrum* are mountain denizens, but none of them would have been expected in this location. This suggests that their introduction may have been inadvertently facilitated by humans and/or their associated vehicles (e.g., visitors, municipal sanitation workers *et al.*). (See also Observation 14 below).

Fig. 4.1 *Andrachne aspera*. All *Andrachne* in WWNP appeared to be *A. aspera*, which is much more common throughout the Hajar Mountains generally than its reported congener *A. telephioides*.

Fig. 4.2. *Convolvulus glomeratus,* a delicate but erect morning glory species without hairy sepals. Its distribution within the Hajar Mountains remains to be carefully delineated and analysed.

Fig. 4.3. *Cymbopogon schoenanthus*. In Arabia, this species has proved difficult to distinguish from *C. commutatus*.

Fig.4.4. *Erodium neuradifolium*, the only *Erodium* identified from WWNP, from among four species recorded in the UAE.

Fig. 4.5. *Launaea bornmuelleri*, seen in WWNP only rarely and at higher elevations.

Fig. 4.6. *Nanorrhinum hastatum*. In the author's opinion, this variable species could prove to be a synomym of *N. ramosissimum* (see bulleted discussion in text under Observation 10).

Fig. 4.7. *Sinapis arvensis*. A few specimens of this ruderal species were found thriving in silt above the Wadi Wurayah dam.

Fig. 4.8. *Stipagrostis hirtigluma*, the only *Stipagrostis* species so far found in WWNP.

Fig. 4.9. *Zaleya pentandra*, an easily overlooked weed of compacted sand and gravel, found in WWNP only in the park headquarters area.

5. 14% of the recorded species (n = 28) were found only in the buffer zones of WWNP, signalling the importance of these marginal mountain and foothills areas for biodiversity.

Twenty-four (24) species, or 12% of the total, were found only in the mountainous buffer zones of upper Wadi Siji and upper Wadi Abadilah in the west and lower Wadi Zikt in the north (Table 2B). This confirms the wisdom of incorporating those areas into the WWNP scheme in order to capture and protect the biodiversity of the mountain environment as a whole.

There is no single explanation for the presence of the buffer zone species. The majority (16) are species found in mountain habitats elsewhere in the UAE that could reasonably be expected within the core zone. One is a plains species that represents an outlier from more extensive populations on the coastal plain (*Haloxylon salicornicum*). Four are associated with agriculture within or at the margin of the Wadi Siji and Wadi Abadilah buffer zones (*Anchusa aegyptiaca*, *Cynodon dactylon*, *Echinochloa crusgalli* and *Medicago laciniata*). Two are outliers of populations that seem to be localised in the Masafi area (*Chaenorrhinum rubrifolium* and *Hyoscyamus muticus*). One is a gravel plains and gravel terrace species which is much more common southwards and for which the WWNP record is among the northernmost known (*Cleome scaposa*).

It is worth noting specifically that the buffer zones in question (upper Wadi Siji, upper Wadi Abadilah and lower Wadi Zikt) do not generally constitute significantly altered or degraded environments. Rather, they appear to be relatively undisturbed mountain environments, at least in UAE terms.

In contrast, Wadi Ghulayyil Khun, which constitutes most of the buffer zone along the eastern edge of WWNP, shows many scars of human contact. It flows through relatively low but still steep and rocky ridges of harzburgite, but those were not sufficient to insulate it from the march of progress. It has a waste dump and a modest dam at its mouth, another dam *ca*. 2 km upstream, and it bears throughout its length the aesthetic indignity of the high voltage power lines that adorn the East Coast skyline, along with the service road used to construct and maintain them. The vegetation does not at first appear to have been much altered by these activities, or by agriculture or human use generally, but the upper part of the wadi shows evidence of grazing. A herd of 30 sheep was observed there during the survey visit, evidently having crossed a low pass from the hinterland of Bidiyah.

For those reasons, it was anticipated that Wadi Ghulayyil Khun might host several anthropophilic plant species not found elsewhere in WWNP (including possible invasive species), but that was not the case.

It was therefore a surprise to find four additional native species (2% of the total) within the newly fenced area of the WWNP headquarters compound, during a serendipitous late-stage reconnaissance in January 2014. The headquarters area is located at the southern extremity of the eastern buffer zone of WWNP, in an environment of rolling gravel pediment traversed by shallow wadis, all in medium to fine gravel.

Despite the coincidence of their presence at WWNP headquarters, there is no suggestion that any of the four species are other than naturally occurring. Two of them, *Eragrostis barrelieri*, an inconspicuous grass, and *Acacia ehrenbergiana* (Fig. 1.29), a large shrub, are locally common in mountain front environments elsewhere in the UAE, and *E. barrelieri* was subsequently found in the WWNP buffer zone in upper Wadi Siji. *A. ehrenbergiana* certainly predates erection of the headquarters fence and buildings. A second small grass, the congener *Eragrostis ciliaris*, is less well known but has been recorded from disused wadi bank fields at low elevation in the Ru'us al-Jibal. The fourth headquarters species is the erect but diminutive, spreading *Zaleya pentandra* (Fig. 4.9), a ruderal species of Aizoaceae found in UAE coastal regions and farms and along the Batinah coast of Oman.

6. 4.0% of the recorded species (n = 8) were found only in Wadi Zikt.

Eight (8) species, or 4% of the total, were found only within the watershed of Wadi Zikt, including one species found only within the buffer zone in Wadi Zikt (Table 2D). Again, this confirms the wisdom of including most of the Wadi Zikt watershed within WWNP. Nevertheless, most of the species in question could reasonably be expected throughout WWNP in suitable habitats, including silt and gravel wadi beds, gravel terraces, wadi walls and gulleys. One exception is *Haloxylon salicornicum*, a sand and gravel plains species which is relatively unlikely to be found within the core zone.

A second possible exception is *Astragalus fasciculifolius*. The only shrubs of this species recorded during the survey or in recent years were several found during the ascent to a low pass (*ca.* 650 metres) formed within one of the large, parallel granitic dikes on the divide between Wadi Zikt and the Wadi Ghayl branch of Wadi Wurayah; two small specimens (one a tiny seedling) were also found in harzburgite in remote upper tributaries of Wadi Zikt. These records suggest the possibility that *A. fasciculifolius* may be intolerant of the ultrabasic rock (harzburgite) that comprises most of WWNP. The author's notes from an excursion to the same area of upper Wadi Zikt in March 1997, in the middle of several exceptionally wet years (Feulner 2006b), describe flowering specimens from "slopes in upper wadi" in the area of the granitic dikes, but without reference to geology.

A. fasciculifolius is common in the Ru'us al-Jibal to the north, in carbonate rock, but the author has encountered it only once to the south of Wadi Zikt. Since it is normally found at elevations of greater than

ca. 400 metres, elevation could be an alternative explanation for why it was not more commonly recorded by the baseline survey. It was recorded by the Wadi Hiluw survey (El-Keblawy 2011), but without habitat or elevation data. *A. fasciculifolius* is believed to be absent regionally between Wadi Hiluw and the Eastern Hajar Mountains, southeast of Muscat, including the intervening and the extensive carbonate massif of Jebel Akhdar. *A. fasciculifolius* was recorded by Mandaville from higher elevations (>1000 metres) at Jebel Aswad, a carbonate area in the Eastern Hajar (Mandaville 1977).

7. The tree flora of WWNP consists of only 7 species, but is typical of the northernmost Hajar Mountains.

Only seven tree species (3.5% of the total naturally occurring species) are found within WWNP:

- *Acacia ehrenbergiana*, typically a large shrub with multiple stems (not a single trunk), known only from the headquarters area of WWNP (Fig. 1.29).
- *Acacia tortilis*, the common acacia or *samr* tree.
- *Ficus cordata salicifolia*, the wadi fig, common along the base of wadi walls to *ca.* 500 metres.
- *Ficus johannis*, the mountain fig (Fig. 1.12), occasional, usually above *ca.* 500 metres.
- *Moringa peregrina*, a wispy tree with filament-like leaves, known by various local names, common on slopes (Fig. 1.13).
- *Prosopis cineraria*, the *ghaf* tree, rare within the mountain environment.
- *Ziziphus spina-christi*, the large, fruit-bearing *sidr* tree, occasional along larger wadis.

This situation is typical of the Hajar Mountains of the UAE and northernmost Oman. Additional tree species and large shrubs can be found in the mountains further south, especially from Wadi Jizzi southwards, both at wadi level and at higher elevations (e.g., *Acridocarpus orientalis*, *Maerua crassifolia*, *Olea europaea*, *Rhus aucheri*, *Sageretia thea*, and *Tamarix aphylla*).

Among larger shrubs, *Dodonaea viscosa* (Fig. 1.8) is present in WWNP; it can grow to a height of two metres or more, but very few large specimens were seen during the survey. Likewise only one large specimen of the woody shrub *Grewia erythraea* was seen; where browsing pressure is heavy, this plant may be browsed to a dense cushion, but that phenomenon was also not seen in WWNP. A few relatively large *Calotropis procera* can be found in the lower wadis within WWNP, but that species is more an opportunist than a mountain species.

Another large shrub, the Desert Thorn *Lycium shawii*, was expected in WWNP but has been recorded only once, historically. Elsewhere it is a species of wadi banks, lower slopes and terraces, and is highly susceptible to browsing. (See also Observation 9.4 below.)

8. Vegetation zones: a lower "wadi zone" can be distinguished from a higher "montane zone".

Additional species appear in the WWNP flora with increasing elevation, although at the relatively modest elevations of most of WWNP (*ca.* 50-900 metres) this normally occurs without significant loss of low elevation species other than those that are tied to the mesic conditions of the main wadi bed. There may be some value in distinguishing, from a floristic point of view, between a "wadi zone" and a "montane zone".

The montane zone is characterised by the regular appearance of species such as *Desmidorchis arabicus*, *Ficus johannis*, *Launaea bornmuelleri*, *Linum corymbulosum*, *Orobanche cernua* and *Pulicaria edmondsonii* and rarer species such as *Bromus danthoniae*. Other species recorded in small numbers at low elevation in WWNP, but generally characteristic of higher elevations elsewhere, are *Helichrysum glumaceum* and *Teucrium stocksianum*.

Because the elevation changes involved are modest, the transition between the wadi zone and the montane zone probably reflects changes in physiography and drainage as much as temperature, rainfall or elevation *per se*. For this reason the elevation of the montane zone is not entirely independent from the overall wadi profile. The base level of the main wadis rises from *ca.* 200 metres at the Wadi Wurayah waterfall to more than 500 metres at the heads of the main branches (Wadi Murtaqam, Wadi Yashimah, Wadi Ghayl *et al.*), with the result that the boundary between the two vegetation zones may vary accordingly, from *ca.* 300-400 metres in the lower and middle reaches of the wadis to *ca*. 500 metres in the upper wadis,

Some of the typical montane species can also occur, atypically, at lower elevations. For example, during the baseline survey occasional seedlings of *P. edmondsonii* were recorded in gravel wadi beds, and two specimens of *F. johannis* are known from wadi level at and below the Wadi Wurayah waterfall.

9. A number of "common" Hajar Mountain species are not common in WWNP, some for reasons that remain to be investigated.

A number of species generally considered to be common in the Hajar Mountains of the UAE were recorded only extremely rarely or not at all during the baseline survey, nor is their presence in WWNP reflected in historical data.

That is a reminder that the Hajar Mountain flora has never been the subject of a fine scale biogeographical study and that a more focused study of WWNP in comparison to other mountain areas has the potential to reveal previously unrecognised biogeographical patterns and insights about ecological relationships and the factors that control plant diversity and distribution in this area.

Most of the absent or rare species were absent unexpectedly. In some cases, upon closer

consideration, those absences can be explained in terms of many of the same factors discussed above in the comparison of WWNP with the Ru'us al-Jibal, including: (i) regional biogeographical gradients; (ii) edaphic differences, i.e., differences in the development and character of the soil or substrate; and (iii) geochemical differences (now, *within* the ophiolite) specifically the difference between ultrabasic (harzburgite) and basic (gabbro) bedrock. In other cases an explanation remains speculative.

9.1. Species that are absent from WWNP without explanation.

Some of the most striking examples of unexpectedly (and so far mostly inexplicably) "absent" species within WWNP are:

- *Erucaria hispanica* (Brassicaceae) (Fig. 5.1). This often hyperabundant pink annual can dominate whole flats, fields, terraces and gravel plains in the Ru'us al-Jibal, along the west flank of the Hajar Mountains, and in the mountains of the Hatta and Masafi areas. It was demonstrably abundant in many such areas on several occasions during the course of the baseline survey, while remaining absent in WWNP. A review of the author's historical records indicates that this species is absent or rare in most other wadis of Shimayliyah and the East Coast generally.
- *Fagonia indica* (Zygophyllaceae) (Fig. 5.2). This distinctive yellow-green, erect, spiny dwarf shrub is common and conspicuous in many areas, favouring silty wadi banks, stony lower slopes and silt accumulations on terraces. In WWNP, however, it was all but absent. A single small specimen of probable *F. indica* was found at a low pass in the WWNP buffer zone in the Nimriyah area of Wadi Zikt. An unequivocal specimen and another enigmatic one were recorded in upper Wadi Siji, again in the WWNP buffer zone. During the period of the baseline survey, *F. indica* was observed elsewhere along the East Coast as a perianthropic ruderal species in the mouth of Wadi Safad, *ca.* 20 km from WWNP, and along a storm drainage channel at the mountain front in nearby Khor Fakkan. Both of those sites are in gabbro environments. That fact raises the initial suspicion that *F. indica* may be among the plant species that are intolerant of ultrabasic bedrock (discussed below), but in fact it is common at many sites along the west flank of the Hajar Mountains, especially south of the Hatta road in Wilayat Mahdhah, Oman, where ultrabasic bedrock prevails.
- *Juncus rigidus* (Juncaceae) (Fig. 5.3). The UAE's only mountain bulrush species is occasional, and locally common, in a number of wadis draining the west flank of the Hajar Mountains, especially in Wilayat Mahdhah, Oman, in locations where the water table is close to the surface. However, a review of the author's historical records indicates that *J. rigidus* is absent or rare in most wadis of Shimayliyah and the East Coast generally, although it can be found north of the Masafi area and as far north as tributaries of Wadi Fa'y, on the south edge of the Ru'us al-Jibal, in each case in ultrabasic bedrock.
- *Lycium shawii* (Solanaceae) (Fig. 5.4). This medium to large sized woody shrub is edible and is often limited elsewhere to sites where it is (or was) protected as a sapling, whether by rocks or other plants. On the East Coast of the UAE it is common as a browsed shrub along wadi banks in Wadi Safad and on hillsides along Wadi Mayy, on the lower slopes of Jebel Qitab, both gabbro environments some 20 km and 40 km south, respectively, from WWNP. But only a single record exists from WWNP, in upper Wadi Yashimah, of a scraggly specimen growing up in a mountain fig *Ficus johannis*. A review of the author's historical records from the Hajar Mountains makes it clear that *L. shawii* is among the species that are intolerant of ultrabasic bedrock (see Observations 9.1 and 9.4 below).
- *Rhazya stricta* (Apocynaceae) (Fig. 5.5). This toxic species is most common in the UAE and Northern Oman on gravel plains, but it is not unusual to encounter it in wadis, especially in or alongside the beds of broader, flatter wadis. The prevalence of *R. stricta* is an indicator of overgrazing. It is present on the East Coast in at least lower Wadi Safad and lower Wadi Mayy, both gabbro environments. Within WWNP, however, it was recorded only at a single, atypical site in the buffer zone, in a steep rubble gulley in upper Wadi Abadilah.
- *Sclerocephalus arabicus* (Caryophyllaceae) (Fig. 5.6). This is a small but sturdy annual of gravel plains and terraces. In February and early March 2013, during the period of the baseline survey, it was locally common on the west flank of the Hajar Mountains in the UAE, but the only record from WWNP is a historical record (based on the author's written description) from the buffer zone in upper Wadi Siji. Jongbloed (2003) had previously mapped it as absent on the east flank of the Hajar Mountains.
- *Teucrium stocksianum* (Lamiaceae) (Fig. 5.7). This edible aromatic is a species of rocky mountain slopes. It is occasional in the Hajar Mountains generally and in the Ru'us al-Jibal, where it is more common at higher elevations (although in many of the more accessible areas it has been reduced in abundance in recent years due to increased browsing by domestic goats). During the period of the

Fig. 5.1. *Erucaria hispanica* (Brassicaceae), an annual that is often profuse on gravel terraces elsewhere in the Hajar Mountains and the Ru'us al-Jibal, but has not been recorded in WWNP.

baseline survey *T. stocksianum* was readily observed on hillsides in Wadi Mayy, along the slopes of Jebel Qitab, southwest of Fujairah, a gabbro environment where it has been recorded historically from *ca.* 200 metres to the summits at *ca.* 1000 metres. In WWNP, however, it escaped notice until two small plants were recorded in a single gulley along the eastern edge of the core zone, in the Powerline Fork of Wadi Ghayl, in March 2014. Another plant was found in May 2014 near the head of a broad scree gulley leading up to a massive granitic dike at the head of Dam Wadi, at ca. 550 metres. Two more scattered plants, healthy and in late flower, were found, anomalously, along the banks of a shallow tributary in the upper reaches of Powerline Fork.

Additional field work and a more detailed review of historical records and relevant botanical literature may help to explain more conclusively the factors that control the presence or absence of the above species, and others, within the Hajar Mountains. As indicated in the descriptions of several of the 'missing' species, the nature of the surrounding bedrock, and specifically the distinction between ultrabasic versus gabbroic (basic) rocks, must be considered as a potentially important element. Nevertheless, ultrabasic geochemistry alone is not a sufficient explanation in all cases. And even if bedrock composition is a determinant of distribution for a particular species, it should not be expected in most cases that the species will be entirely excluded from the disfavoured environment.

It is possible, among other things, that the geochemistry of certain habitats, e.g., wadi pools, wadi beds with thick gravel, silt accumulations, and perhaps even gravel plains (and the subsurface weathering beneath them), can effectively mitigate the adverse effects of the ultrabasic environment and permit the growth of species that would otherwise be intolerant of it. Climatic factors, particularly rainfall, may also attenuate at least some of the rigours of the ultrabasic environment. For example, the development of the most extremely alkaline groundwater depends on the slow percolation of relatively small amounts of groundwater through relatively large amounts of ultrabasic bedrock, so a higher rainfall regime is associated with lower groundwater alkalinity (Clark & Fontes 1990). This has, potentially, both short-term and long-term effects on the local flora. In the short-term, above average seasonal rainfall could insulate many annual species from what would otherwise be difficult or prohibitive chemical parameters of the ultrabasic environment. From a long-term perspective, it could mean that the Hajar Mountains were a somewhat more geochemically hospitable place for perennial species during past intervals of increased rainfall.

The three sections immediately below give examples of some plant species whose UAE distribution can be assigned with reasonable confidence to: (i) regional biogeographic gradients; (ii) edaphic factors; or (iii) the presence or absence of ultrabasic bedrock.

All of these examples suggest that a more detailed study of plant distribution, taking careful account of geology, geography and biogeographical history, as well as microhabitats, has the potential to result in

Fig. 5.2. *Fagonia indica*. This distinctive Hajar Mountain species was the first to be noticed by the author as "missing" in WWNP.

Fig. 5.3. *Juncus rigidus*, (the very spiky plant in the foreground and in the water at centre), a bulrush generally common in wet wadis of the Hajar Mountains but absent on the east flank of the mountains in the UAE. (Picture by Binish Roobas)

Fig. 5.4. *Lycium shawii*, the "Desert Thorn", seen here on a recently flooded wadi bank, may be intolerant of the ultrabasic geochemistry of the bedrock of WWNP.

Fig. 5.5. *Rhazya stricta*, whose profusion is an indicator of overgrazing.

Fig. 5.6. *Sclerocephalus arabicus*. This species appears to be absent on the east flank of the Hajar Mountains in the UAE, for reasons so far unknown.

Fig. 5.7. *Teucrium stocksianum.* This edible mint family member was inexplicably rare in WWNP, a few healthy plants being found in a remote high elevation location, and a few others on a low wadi bank accessible to browsing animals.

enlightening generalisations. Conversely, they indicate that it is dangerous to generalise without an examination of individualised circumstances.

9.2. Species whose biogeographical range does not extend to WNPP.

Five of the common Hajar Mountain species highlighted in Table 5 of Feulner (2011) ("Common Hajar Mountain species that are absent or very rare in the Ru'us al-Jibal") are absent in WWNP as well as the Ru'us al-Jibal, because both of those areas are situated beyond the regional biogeographical range of the species in Eastern Arabia.

All of these species, as it happens, are relatively large and/or conspicuous. They include the trees *Olea europaea* (the wild olive) and *Maerua crassifolia*, the large shrub *Acridocarpus orientalis*, and the dwarf palm *Nanorrhops ritchieana*, all of which are more common to the south, in the mountains of Northern Oman (and, in the case of *N. ritchieana*, on the plains of Central Oman). Nevertheless, all of the foregoing species except *A. orientalis* are also found in the Makran region, i.e., the coast and hills of southern and southwestern Pakistan.

The toxic perennial composite *Iphiona aucheri* is perhaps a recently arrived species; it is centred in the foothills south of the Hatta road in Wilayat Mahdhah and has not been found further north, although it has been recorded as far south as Jebel Hafit (A.R. Western, *pers. comm.*).

9.3 Species that are absent or rare in WWNP for edaphic reasons.

The ghaf tree *Prosopis cineraria* is primarily a species of sand and gravel plains, but it is not unusual to encounter it in or adjacent to broader, flatter gravel wadis within the Hajar Mountains. Yet although it is reasonably common on the plains of the East Coast, it is rare in WWNP, where anthropogenic influence is suspected for its presence at the three recorded sites. Edaphic (soil/substrate) and hydrologic factors are the most likely explanations for its absence in the more rugged wadis of the Hajar Mountains, including WWNP. *P. cineraria* is a notoriously deep rooted species and it may be unable to penetrate the generally shallow ophiolite bedrock.

In some cases, drainage characteristics of the substrate may be the principal determinant of distribution. Among the best examples are the two *Lindenbergia* species (*L. arabica*, which is endemic to the UAE and Oman, and *L. indica*). Both are typically found on, or at the base of, the vertical wadi walls of coarse gravel terraces – an extremely common habitat in the Hajar Mountains. The gravel terraces serve, among other things, as reservoirs for the slow downward percolation of groundwater. However, both *L. arabica* and *L. indica* have proved to be rare in WWNP relative to their abundance in the Hajar Mountains to the south. One possible explanation for this is lower rainfall in the northernmost Hajar Mountains (see Feulner (2011) at Sections 8.4, pp. 80-81, and 9.1, pp. 91-92), and therefore less percolating water. Another possibility is that the large size of the Wadi Wurayah watershed channels floodwaters higher in the main wadis, dislodging the typically low-growing *Lindenbergia* species and restricting them to tributary wadis, where gravel terraces are often less well-developed.

9.4. Species whose distribution may be controlled by the presence or absence of ultrabasic bedrock.

The author has previously recognised three plant species – *Capparis cartilagenia*, *Ducrosia anethifolia* and *Koelpinia linearis* – that appear to be limited in the UAE and Northern Oman to areas of carbonate bedrock, specifically, the Ru'us al-Jibal and intermittent mountain front ridges and massifs such as Jebel Fayah, Jebel Rawdhah, Jebel Sumayni, Jebel Ghawil, Jebel Qatar and Jebel Hafit, being absent from the ophiolite rocks of the main Hajar Mountains (Feulner 2011, Section 6.2).

The results of the baseline survey further suggested to the author a number of plant species whose distribution *within* the ophiolite bedrock of the appeared to be sensitive to the presence or absence of ultrabasic bedrock. These included both species recorded in WWNP and species absent from it. In order to make a preliminary assessment of that possibility, reference was made to the author's field records from selected excursions throughout the Hajar Mountains and surrounding areas. This was supplemented by contemporaneous investigation of two non-ultrabasic locations within the Hajar Mountains – Jebel Qitab and Wadi Sfai, both situated in areas of gabbro bedrock.

That effort confirmed some hypotheses, eliminated some others, and left still others for additional targeted field and literature investigation and future elaboration. In the case of a few rare species, the total number of records is insufficient to support firm generalisations. Some preliminary conclusions are presented in summary fashion below.

(i) <u>Species that strongly 'favour' ultrabasic bedrock environments</u>
Diplotaxis harra (Brassicaceae)
Gypsophila bellidifolia (Caryophyllaceae)
Pteropyrum scoparium (Polygonaceae)
Salvia macilenta (Lamiaceae)

(ii) <u>Species that weakly 'favour' ultrabasic bedrock environments</u>
Cleome rupicola (Capparaceae)
Haplophyllum tuberculatum (Rutaceae)
Pulicaria edmondsonii (Asteraceae) [also limited to high elevation]

(iii) <u>Species that strongly 'avoid' ultrabasic bedrock environments</u>
Convolvulus acanthocladus (Convolvulaceae) [also limited to high elevation]

Dicoma schimperi (Asteraceae)
Echiochilon persicum (Boraginaceae)
Lycium shawii (Solanaceae)

(iv) Species that weakly 'avoid' ultrabasic bedrock environments
Phagnalon schweinfurthii (Asteraceae) [also limited to high elevation]
Vernonia arabica (Asteraceae) [also limited to high elevation]

It is also possible that the unexpected distribution of certain congeneric species in WWNP (see Observation 11 below) may be influenced by the presence or absence of ultrabasic bedrock, but this has not yet been investigated.

It bears remarking that, somewhat counterintuitively, the above allocation of species does not bear a straightforward relationship to their presence or absence in the carbonate rocks of the Ru'us al-Jibal range. Five of the six species that appear to 'avoid' ultrabasic rock are common or occasional in the Ru'us al-Jibal (the sixth is absent), but three of the seven species that 'favour' ultrabasic bedrock are also locally common in the Ru'us al-Jibal (three others are rare and one is absent) (Feulner 2011).

9.5. Elevation as an additional control on distribution.

In a few cases, elevation (which is to some extent a surrogate for temperature and moisture) may be an equally or more important factor than geochemistry in determining the distribution of sensitive species. *Ephedra pachyclada* and *Phagnalon schweinfurthii* are two higher elevation species that, outside the Ru'us al-Jibal, are found in the UAE almost exclusively in the Olive Highlands (Feulner 2014), an extensive area of gabbroic rock, on ridges and plateaux at elevations of ca. 800 to 1050 metres. With the exception of a single *P. schweinfurthii*, neither species has been found within WWNP, but this may be primarily because the total area in WWNP at elevations of 800 metres and above is small, and consists of steep, narrow and inhospitable ridges. Both species have been found within ultrabasic rocks to the south, in the mountains southeast of Jebel Hatta, although only at much higher elevations (ca. 1400 metres).

10. Additional species are certain to be found in WWNP. Some likely candidates are suggested.

No survey can claim to have revealed all plant species present in such a large and difficult area as WWNP. The many sole records, historical records, and records of rare or short-lived annuals emphasise the importance of contingency and of being in the right place at the right time. For these reasons, it is inevitable that additional species will be added to the Checklist over the course of time.

That said, some species are more likely than others to be found in WWNP in the future. Any of the "missing" species discussed above in Observation 9 is possible, at least in small numbers; the expectation that they should be present is what makes their absence noteworthy. They would be precluded only if some parameter of the WWNP environment proves to be an absolute bar to their presence.

It is also reasonable, as a general matter, to expect that several additional grass species (Poaceae) will be recorded over time. Many grasses are both inconspicuous and seasonal, and some could have been overlooked. Several of those that are more likely to occur are included in the list below.

For a few genera of UAE mountain plants, closely similar congeners have been recorded in the literature. With that in mind, the author made the effort to distinguish between them and to ascertain whether multiple congeners might be present in WWNP, with results as follows:

- For *Andrachne*, only *A. aspera* (Fig. 4.1), (not *A. telephioides*) was recorded. (See the discussion in the Checklist.)
- For *Cymbopogon*, only *C. schoenanthus* (Fig. 4.3) (not *C. commutatus*) was recorded. (See the discussion in the Checklist.)
- For *Digitaria*, only *D. nodosa* (Fig. 3.5) (not *D. ciliaris* or *D. sanguinalis*) was recorded. (See the discussion in Observation 11 below and the Checklist.)
- For *Erodium*, only *E. neuradifolium* (Fig. 4.4) (and none of several similar congeners) was recorded. (See the discussion in Observation 11 below and the Checklist.)
- For *Geranium*, of three similar congeners, two species (*G. biuncinatum* (Fig. 3.9) and *G. trilophum* (Fig. 3.10)) were recorded during the survey; *G. mascatense* was not. (See the discussion in Observation 11 below and the Checklist.)
- For *Nanorrhinum*, only *N. hastatum* (Fig. 4.6) (not *N. ramosissimum*) was recorded. (See the discussion below in this Observation 10 and in the Checklist.)
- For *Stipagrostis*, only *S. hirtigluma* (Fig. 4.8) (and none of several similar congeners) was recorded. (See the discussion in Observation 11 below and the Checklist.)

These results are briefly discussed in the relevant entries in the Checklist. *Digitaria*, *Erodium*, *Geranium* and *Stipagrostis* are also discussed separately below in Observation 11, because the species recorded in WWNP are not the ones generally considered to be the most common in those genera. It is possible, however, that some or all of the unrecorded congeners could also be present in WWNP.

Below is a short list of additional species which, in the author's opinion, are among the most reasonable candidates to be found in WWNP, at least in small

numbers. The list attempts to take account of the author's experience in neighbouring mountain areas including the Ru'us al-Jibal (Feulner 2011), the highlands of Jebel Qitab and the surrounding watersheds of Wadi Hayl, Wadi Hiluw, Wadi al-Iyeli and Wadi Sfai (El-Keblawy 2011, Feulner 2014), and the ultrabasic mountains in the Hatta area and southwards, as well as general floral accounts for the UAE and Northern Oman. However, any such list is inevitably somewhat arbitrary, and other prospective species could also be suggested.

- *Cenchrus* spp. (Poaceae): *Cenchrus* spp. were collected intermittently during the course of the survey, and the spikelets were examined in the field or laboratory, but all proved to be *C. ciliaris*. However, *C. pennisetiformis* and *C. setigerus* have been recorded by others, including from the mountains of the East Coast (Jongbloed 2003, El-Keblawy 2011), and could therefore be present in WWNP.
- *Cleome brachycarpa* (Capparaceae): This species is locally common along the plains of the East Coast, as shown in Jongbloed (2003) (although contrary to what is stated in Jongbloed (2003), it does not favour limestone outcrops, which are not found on the East Coast). In January 2013, during the course of the survey, *C. brachycarpa* was common on the irrigated gabbro hillside above Suwaifah Park on the northern outskirts of Khor Fakkan town, only *ca.* 5 km from the mouth of Wadi Wurayah. It is possible that this species may be somewhat intolerant of ultrabasic bedrock and/or may depend on relatively mesic conditions, including above average rainfall. *C. brachycarpa* has been recorded locally among ultrabasic rocks (harzburgite) in the mountain foothills of Al-Fay, Oman, near Hatta, UAE (as also shown in Jongbloed (2003)), but there it is associated with freshwater springs and outcrops of tufa, a carbonate rock precipitated by the reaction between the highly alkaline groundwater in the ultrabasic bedrock and atmospheric CO_2. In any case, because of its presence in proximity to WWNP, *C. brachycarpa* could potentially be found serendipitously on the eastern margin the park.
- *Convolvulus prostratus* (Convolvulaceae): This spreading ruderal species is found in waste ground on the East Coast and could occur within WWNP, especially in or near the buffer zone on the eastern margin.
- *Cosentinia vellea* (= *Cheilanthes vellea*) (Pteridaceae): Elsewhere in the UAE and Northern Oman, this fern species is more or less sympatric with *Cheilanthes acrostica*, which has already been recorded in WWNP. If *C. vellea* is not found within WWNP, then the chemistry of the ultrabasic rocks could be the explanation.
- *Dichanthium annulatum* (Poaceae): This species, which the author has never knowingly encountered, is nevertheless mapped by Jongbloed (2003) as widespread but not common over most of the northern UAE, including mountain areas, and it was recorded by El-Keblawy (2011) in Wadi Hiluw.
- *Eliocharis geniculata* (Cyperaceae): This delicate sedge is typically found at the margins of shallow pools and on adjacent damp ground. It would be reasonable to expect it in the area of the Wadi Wurayah waterfall and perhaps at selected pools in upstream areas.
- *Erodium laciniatum* (Geraniaceae): Consistent with the baseline survey results, Western (1989) found *E. neuradifolium* to be the most common mountain *Erodium*. However, Jongbloed (2003) has mapped *E. laciniatum* in mountain areas in the UAE. Patzelt, in Ghazanfar (2007), reports *E. laciniatum* from lower elevations (20-500 metres) in Northern Oman and the Musandam region, and considers it more commonly collected than other *Erodium* spp. If it proves not to be present in WWNP, the ultrabasic environment may be the most likely explanation. (See also Observation 11 below.)
- *Geranium mascatense* (Geraniaceae): This species has generally been reckoned the most common of the *Geranium* species in the Hajar Mountains (Western 1989, Jongbloed 2003, Karim & Fawzi 2007), so it would be curious if (as so far appears) it is absent in WWNP, given that its two local congeners (*G. biuncinatum* and *G. trilophum*) are present. However, during the period of the baseline survey, *G. mascatense* was collected in a wadi on the slopes of Jebel Qitab, in gabbro bedrock southwest of Fujairah city, where it was the only *Geranium* species identified. This suggests that it could prove to be another species that is intolerant of the ultrabasic environment of WWNP. (See also Observation 11 below.)
- *Linaria* spp. (Scrophulariaceae): *L. simplex* and *L. tenuis* have both been recorded from mountain areas of the UAE (Jongbloed 2003, Karim & Fawzi 2007, El-Keblawy 2011, Feulner 2011), but both are diminutive annuals that could easliy escape notice.
- *Nanorrhinum ramosissimum* (Scrophulariaceae): This species is very similar to *N. hastatum* and could have been overlooked. Both have similar flowers but both are otherwise variable in appearance and habit. Geographically, *N. hastatum* is a species of northeast Africa and Arabia (Boulos 2002), whereas the principal range of *N. ramosissimum* is in Iran,

Afghanistan and Pakistan (Nasir & Rafiq 1995). This raises at least the possibility that the two species may yet be synonymised, based on investigations from the area where they "meet", in the Hajar Mountains of the UAE. There is precedent for this result in the recent synonymisation by Norbert Kilian of two Asteraceae pairs having analogous distribution patterns, *Helichrysum glumaceum* and *H. makranicum*, and *Phagnalon schweinfurthii* and *P. viridifolium* (Feulner 2011).

- *Pulicaria arabica* (Asteraceae): This spreading species is typically found on damp ground at the margins of shallow pools. It would be reasonable to expect it in the area of the Wadi Wurayah waterfall and at pools in upstream areas.
- *Sisymbrium irio* (Brassicaceae): This species is very similar to *S. erysimoides*, which is occasional within WWNP, usually at shaded or sheltered sites among other annuals. *S. irio* was mapped by Jongbloed (2003) throughout the mountains of the UAE, but as "uncommon". In the course of the baseline survey, in most instances no attempt was made to distinguish between the two *Sisymbrium* spp., but the occasional fruits that were examined all appeared to be *S. erysimoides*. However, both species were recorded from Wadi Hiluw by El-Keblawy (2011). *S. erysimoides* was found there in both natural habitats and plantations; no habitat information is given for *S. irio*.
- *Stipagrostis* spp. (Poaceae): Western (1989) and Jongbloed (2003) both mapped *Stipagrostis plumosa* throughout the mountains of the East Coast, including the Ru'us al-Jibal, and El-Keblawy (2011) has recorded it from Wadi Hiluw. Feulner (2011) recorded *S. raddiana* (= *S. paradisea*) from higher elevations in the Ru'us al-Jibal, based on determinations by the late Prof. Hildemar Scholz. The field appearances of *S. hirtigluma* and *S. raddiana* are very similar. *S. ciliata* is distinctive in appearance and is locally common in the mountains in the Mahdhah area of Northern Oman The author is aware of no actual determinations of material collected from WWNP other than the multiple determinations of *S. hirtigluma* made in the course of the baseline survey, but any of the above-mentioned *Stipagrostis* spp. could possibly occur. (See also Observation 11 below.)
- *Tribulus* spp. (Zygophyllaceae): Both *T. parvispinus* and *T. pentandrus* are prostrate or spreading species similar in appearance to *T. terrestris*, and are difficult to distinguish when not in fruit (Western 1991, Jongbloed 2003). *T. parvispinus* has been recorded from the East Coast of the UAE and *T. pentandrus* has been recorded from the UAE mountains generally. Prostrate *Tribulus* plants found during the course of the baseline survey were regularly examined. All plants found in fruit were determined to be *T. terrestris* and no plants were found which appeared inconsistent with *T. terrestris*.

Finally, the silt accumulations found for *ca.* 1-2 kilometres in the basin and wadi bed above the Wadi Wurayah dam constitute an environment that could be colonised by a number of species not normally found in the mountain environment, especially ruderal ones. Similar but less extensive silt accumulations on gravel banks at Tennis Club Dam, on the outskirts of Fujairah, host, e.g., *Amaranthus viridis*, *Portulaca oleracea* and *Tephrosia nubica* (for the latter, this is believed to be the northernmost record in the region). *Amaranthus albus* and *Emex spinosa* are additional examples of species that might occur opportunistically in the alluvial silt environment, although both appear to be rare on the East Coast. *Corchorus depressus* is another such species, and was recorded from a single silted, bulldozed terrace site in lower Wadi Ghayl.

11. The relative abundance of certain congeneric species must be reassessed, at least within the ultrabasic mountain environment.

For several plant genera represented in the UAE by multiple species, the species found to be the most common within WWNP were previously considered to be uncommon:

- *Digitaria* (Poaceae): All of the widespread, scattered specimens of *Digitaria* collected within WWNP are believed to be *D. nodosa* (Fig. 3.5), consistent with the historical record of that species from Wadi Wurayah (by Curtis, 03/1998). *D. nodosa* is an extremely variable species and specimens collected during the baseline survey exhibit the full range of variation, but with a few consistent features. Spikelets of *D. nodosa* and other potentially relevant *Digitaria* species (*D. ciliaris*, *D. sanguinalis* and *D. velutina*) are depicted rather differently in illustrations in Boulos (2004) and Cope (2007), but keys in both of those references encourage primary reliance on the gross form of the plant, *D. nodosa* being distinguished as an erect, tufted perennial without rhizomes. Cope (2007) is expressly sceptical of UAE and other Arabian records of *D. sanguinalis* but he also maps the only published record of *D. ciliaris* from the UAE's East Coast.
- *Erodium* (Geraniaceae): All collected specimens of *Erodium* spp., determined by examination of the fruiting parts, proved to be *Erodium neuradifolium* (Fig. 3.4), not *E. laciniatum*, although the latter is considered by recent authors to be the most common *Erodium*

species (Jongbloed 2003, Patzelt writing on Geraniaceae in Ghazanfar 2007). However, Western (1989) regarded *E. neuradifolium* as "Common in mountains at all elevations; occasional along east coast slopes".

- *Geranium* (Geraniaceae): Field identifications and collected specimens of *Geranium* spp., likewise determined by examination of the fruiting parts, proved to be predominantly *Geranium biuncinatum* (Fig. 3.9), with two collections of *G. trilophum* (Fig. 3.10). *G. muscatense*, which has heretofore been treated as the most common *Geranium* species in the UAE (Jongbloed 2003, Karim & Fawzi 2007) was not recognised within WWNP, although it was collected during the period of the survey on the slopes of Jebel Qitab, in gabbro bedrock, southwest of Fujairah city.
- *Stipagrostis* (Poaceae): All collected specimens of *Stipagrostis* spp. from WWNP, and all of the many *Stipagrostis* specimens that were examined in the field, proved to be *Stipagrostis hirtigluma* (Fig. 4.8). Previously *S. plumosa* had been reckoned to be the predominant *Stipagrostis* species and was mapped as present in the UAE mountains by Western (1989) and Jongbloed (2003). Jongbloed (2003) mentioned records by others of *S. hirtigluma* "from the southern Hajar Mountains".

It is possible that the distribution of some of the above congeners may be influenced by the presence or absence of ultrabasic bedrock (see Observation 9.4 above), but this has not yet been investigated in detail.

12. A number of species flowered in winter in response to autumn rains, ignoring low temperatures.

A number of species, both annuals and perennials, flowered in winter, evidently in response to autumn rains, ignoring relatively low temperatures. This phenomenon was observed both in Wadi Zikt in mid-January 2012 and in Wadi Wurayah in January 2013. In most cases this meant that flowering occurred somewhat earlier than the generally recognised flowering period for the concerned species, as set out in Jongbloed (2003), Ghazanfar (2003, 2007) and Karim & Fawzi (2007).

Among the species recorded in flower in January 2013 and January 2014 were the following:

Annuals	Perennials
Anagallis arvensis	*Aerva javanica*
Arnebia hispidissima	*Aizoon canariense*
Asphodelus tenuifolius	*Andrachne aspera*
Cleome rupicola	*Boerhavia elegans*
Cuscuta planifora	*Cenchrus ciliaris*
Eragrostis cilianensis	*Convolvulus virgatus*
Erodium neuradifolium	*Desmidorchis arabicus*
Euphorbia arabica	*Haplophyllum tuberculatum*
Lotononis platycarpa	*Heliotropium brevilimbe*
Nanorrhinum hastatum	*Leucas inflata*
Ophioglossum polyphyllum	*Periploca aphylla*
Plantago spp.	*Salvia macilenta*
Polygala erioptera	*Tricholaena teneriffae*
Rumex vesicarius	
Sisymbrium erysimoides	
Tribulus terrestris	

13. The survey emphasises the ephemeral nature of even some very common annual species, with implications for floral assessments.

Timing is everything, especially for many annual species. This is a simple but very important statement that is emphasised by the survey results. A few examples will illustrate the point.

The dock *Rumex vesicarius* (Polygonaceae) was hyperabundant in January through March 2012. In many places it dominated the overall impression of the wadis and wadi slopes, in terms of colour and vegetative cover. But by June, only occasional dried plants were seen, and it was possible to overlook it.

Silene austroiranica (Caryophyllaceae) is an erect but wispy annual that rolls up its petals during the heat of the day. It is not conspicuous at a distance but was common underfoot in many habitats by early March 2013 and a few were still in flower through early June 2013. Yet it would be possible to walk the wadis for most of the rest of the year without seeing it at all.

Finally, the compact Adder's Tongue fern *Ophioglossum polyphyllum* (Ophioglossaceae) was seen only in December 2012, dotting small silted plots on a gravel terrace above the waterfall area, where it may reflect ancient cultivation. In more than twenty years, the author had never before seen this species, and when the site was re-visited in March 2013, there was no trace of it.

14. No invasive plant species were recorded within WWNP.

No exotic species, invasive or otherwise, were encountered at wild sites within WWNP, notwithstanding the large scale introduction of dry-adapted exotic plants for landscaping in the UAE as a whole over the past 40 years, including the East Coast. This may be an oblique tribute to the rigours of the local environment.

In particular, the introduced mesquite tree, *Prosopis juliflora*, the only UAE plant species generally regarded as invasive in natural environments, was not recorded within WWNP, although it has spread extensively on the sand and gravel plains and waste ground of the East Coast, bordering the mountains. *P. juliflora* is now considered a pest species in many countries where it has been introduced, including Oman, but eradication efforts have generally not proven successful. With respect to its status in the UAE, the view has been expressed that, at this point, *P. juliflora* has already spread to all places where it can thrive (A. El-Keblawy, *pers. comm.*). If so, then only significant disturbance of the environment within WWNP would pose a threat from this invader.

Four exotic species have been recorded as isolated specimens in the area of the Wadi Wurayah waterfall. Three of them are edible fruit or vegetable species – watermelon *Citrullus lanatus*, tomato *Solanum lycopersicum* and mango *Mangifera indica* – and one is an Asian landscaping or amenity species (the 'peepul' tree *Ficus religiosa*) found only rarely in older urban areas of the UAE. The mango and peepul are both large trees when mature, but in WWNP they were seen only as seedlings, both growing on the edge of a cemented channel just above the waterfall, and in almost exactly the same place, although several years apart. *M. indica* was encountered only in summer 2009; two large glossy leaves had sprouted from a mango pit that had been scraped clean and discarded by picnickers. The *F. religiosa* was present throughout most of the baseline survey; it had a substantial woody rootstock but did not appear to have increased in size. However, it was not seen following a flash flood in early November 2014.

A few additional watermelon plants were found on fine gravel beside the lower road crossing in Wadi Ghayl. The area was used as a parking place during several baseline survey excursions and it is possible that other visitors, including picnickers, may also have made use of the same convenient location.

Several of the other species found only in the waterfall area, or at pull-off areas along the paved road leading to it, can be considered 'indigenous exotics' – i.e., native species that have somehow been transported to WWNP from their customary environments within the UAE. Most likely this has been by human agency, but most likely, too, it has been inadvertent, probably by vehicles traveling quickly and effortlessly from one environment to another. The best example is the large shrub of *Leptadenia pyrotechnica* on a visitor-friendly gravel plain along the access road; another much smaller plant was subsequently discovered in a wadi bed nearby.

Other examples of indigenous exotics include *Dichanthium foveolatum*, *Launaea procumbens*, *Physalis minima* and *Sporobolus spicatus*. *Campanula erinus* and *Lotus schimperi* are much less common and less likely to be encountered by people and vehicles. They are perhaps more likely to have arrived at the waterfall area by natural means and thrived in the anthropogenic environment. In any case, there is no evidence that any of the above species have spread or will spread within WWNP.

Two conspicuous species that have arguably proliferated to the point of inconvenience are the tall reed *Arundo donax* (in Waterfall Wadi) (Fig. 5.18) and the ground melon *Citrullus colocynthis* (in the area behind the dam), but these species cannot be regarded as invasive. They are simply colonising habitat for which they are specialised, at a time when conditions are favourable. The author has visited Waterfall Wadi on several occasions since the mid-1980s and has found the reed population to be variable. It had not, until December 2012, proved to be a serious impediment to passage.

Wadi Ghulayyil Khun occupies most of the buffer zone along the eastern edge of WWNP and debouches directly onto the coastal plain on the outskirts of an area of mixed agriculture and the industrial fringe of modern Bidiyah. It has a waste dump and a modest dam at its mouth, and another dam *ca.* 2 km upstream. As noted above in Observation 5, this wadi was visited in the expectation that it would host several anthropophilic species not found elsewhere in WWNP, including possible invasives, but that was not the case.

15. Evidence of browsing within WWNP is limited and largely restricted to tributaries of lower and mid-Wadi Ghayl.

Evidence of browsing or grazing was extremely limited throughout most of the areas surveyed, consistent with the rather small number of free-ranging browsers (mostly feral goats) observed during the course of the survey. A total of twenty (20) feral goats were sighted during the course of the baseline survey, almost all of them on slopes in the upper reaches of Wadi Wurayah and Wadi Murtaqam in the southern portion of WWNP, and goat droppings were generally rare. Similarly, only 12 feral donkeys were observed, all within the WWNP buffer zone in upper Wadi Siji, and eight of them not far from a plantation on the border of the buffer zone. However, donkey droppings and trails were encountered in mid-Wadi Ghayl and its tributaries, which are evidently in current use by at least a small local population. A programme of camera trapping by WWNP researchers has been underway for several years for the purpose of a more accurate assessment of the browsing population.

A goat farm, with an average of approximately 60-80 goats in residence, is situated near the head of a small tributary wadi along the access road to the waterfall. The farm pre-dates the creation of the WWNP protected area and has been allowed to remain. The goats graze regularly in the surrounding area, including lower Wadi Ghayl, under the supervision of a shepherd (J. Judas and M.K. Shuriqi, *pers. comm.* 2014; *pers. obs.*)

Otherwise, what evidence of browsing existed seemed largely confined to: (1) the uppermost ridges on the divide between Wadi Murtaqam and upper Wadi Siji; (2) mid and lower Wadi Ghayl and its tributaries, including the open plains bordering the Powerline Fork and the Aqabat al-Kharus area; and (3) upper Wadi Ghulayyil Khun. The latter two areas feature relatively gentle terrain and are relatively accessible; browsing there is at least partly by domestic livestock (see below). The first area, however, is remote and difficult for humans and larger quadrupeds.

The impression given was that browsers may enter these areas intermittently from outside the core zone and/or outside WWNP. That impression was subsequently confirmed by personal observation in the case of Wadi Ghayl and Wadi Ghulayyil Khun. The low pass from the Nimriyah area of Wadi Zikt into a tributary of mid-Wadi Ghayl has a well established animal trail with occasional donkey droppings and a clump of *sidr* trees (*Ziziphus spina-christi*) evidently used as a donkey scratching post.

In mid-July 2014, a loose herd of 9 domestic goats (they did not flee from close approach) was seen in Powerline Fork, a lower tributary of Wadi Ghayl. This herd was only very lightly supervised. The shepherd, an Asian expatriate employed by an owner from Bidiyah, was encountered *ca.* 2 kilometres away, near Aqabat al-Kharus. When asked how many animals he tended and where they were, he shrugged and gestured broadly to the surrounding area. He said he visited regularly, sometimes by motorcycle, but he explained that access was also possible directly from Bidiyah by a steep trail in the upper wadi. Later the same month, a herd of about 25 mostly black-faced sheep were seen in the same area, apparently unsupervised. One female lagged behind to give birth, but ignored her bleating infant; by the time of our return in late evening, the newborn lamb had been killed and eaten, probably by a fox.

In Wadi Ghulayyil Khun, an unaccompanied flock of *ca.* 30 sheep was observed in the uppermost wadi in mid-December 2013, heading downstream along a defined animal trail descending from a low and relatively gentle pass (*ca.* 200 metres) connecting to the Bidiyah area. Sheep are typically grazers, but these were observed to browse (selectively) on shrubs of *Hibiscus micranthus*.

Historically, only feral goats and Arabian tahr, and no feral donkeys (or donkey droppings), were observed in Wadi Wurayah above the waterfall area. The absence of donkeys probably reflects the difficult access from downstream for larger vertebrates, particularly the obstacle of the gorge and pools commencing at the head of the vehicle track in the main wadi, and similar obstacles in the waterfall wadi itself. Moreover the steep slopes and difficult access to many tributary wadis of upper Wadi Wurayah (Wadi Murtaqam) and Wadi Yushemah make that area inhospitable to feral donkeys.

Among the perennial species known to be especially susceptible to browsing are:

- *Convolvulus virgatus* (Convolvulaceae), sometimes browsed to a cushion.
- *Grewia erythraea* (Tiliaceae), a woody shrub sometimes also browsed to a cushion.
- *Hibiscus micranthus* (Malvaceae), an erect shrub which in upper Wadi Ghulayyil Khun was seen to be selectively browsed by sheep and was generally observed only where it grew within the protection of larger, unpalatable shrubs.
- *Phagnalon schweinfurthii* (Asteraceae), recorded only from a single WWNP location at anomalously low elevation in lower Wadi Ghayl.
- *Teucrium stocksianum* (Lamiaceae), an aromatic which has been recorded at only three WWNP locations. (Paradoxically, however, one of those locations was high in the Powerline Fork of Wadi Ghayl, in the Aqabat al-Kharus area, which is definitely subject to grazing.)

It should be emphasised that browsing does not seem to bear a simple relationship to plant diversity. Specifically, the tributaries of mid-Wadi Ghayl, identified here as the principal area where evidence of browsing and the presence of browsers have been observed, also represent one of the environments that has been identified as having the highest levels of plant diversity (see Observation 4 above).

Recommendations for future botanical research

In addition to its obvious value from the standpoint of conscientious, data-based future management of Wadi Wurayah National Park, the baseline survey provided the occasion for a far more intensive investigation and analysis of the flora of a remote area of the Hajar Mountains than any that has previously been conducted. So it is perhaps not surprising that it has produced many interesting results that invite further inquiry. The questions posed for future research fall into four basic categories:

- Refinement of our understanding of the distribution of various plant species within the Hajar Mountains and elucidation of the factors that control their distribution; in particular, the identification of species that may avoid, or may be specially adapted to, the extensive ultrabasic bedrock environment of the Hajar Mountains, and the physiological adaptations that ultrabasic 'specialist' species may exhibit.
- Collection and taxonomic review of material belonging to problematic genera represented in the UAE by multiple species, to ascertain which of those species are in fact represented, and in what environments. Some genera which should be targeted in this effort are *Erodium*, *Geranium* and *Stipagrostis*.
- Additional botanical collection, during propitious conditions, with special attention to (i) grasses (Poaceae), of which it is reasonable to expect that at least a small number of additional species will be added to the WWNP list, and (ii) higher elevation habitats (including possible crack-dwelling and scree-dwelling species).
- Investigation of the plant species most favoured by browsing quadrupeds and the effect of browsing (or grazing) on those species. In the apparent absence of a significant population of feral browsers within most of WWNP, and given the extreme difficulty of observing or tracking them, an indicative proxy approach might focus on the herds of domestic browsers occasionally found within lower Wadi Ghayl and its tributaries, particularly the Aqabat al-Kharus area. This could involve the establishment and comparison of areas protected from browsing over a period of time.

Acknowledgements

The baseline survey reported here was commissioned by EWS-WWF and and sponsored by HSBC. HSBC deserves special commendation for its continuing commitment to conservation and to research in WWNP, commencing with its sponsorship of the study to evaluate the potential and feasibility of the creation of a protected area (EWS–WWF 2006), which represents, overall, one of the best single references available concerning the wadi environments of the of the UAE.

Dr. Marijcke Jongbloed and John Martin made helpful comments on an early draft of this report. Dr. Jongbloed also provided the identification of *Zaleya pentandra*, which might otherwise have remained unknown, and saved the author a great deal of time and effort by identifying an enigmatic seedling of *Plantago afra*. Dr. Norbert Kilian identified and corresponded about the newly recognised UAE/Oman endemic *Launaea omanensis*, and confirmed the identification of *L. procumbens*. Dr. Jacky Judas conscientiously prepared Map 2, showing the field coverage represented by the baseline survey and historical field excursions by the author.

The author wishes to extend his personal thanks to Dr. Olivier Combreau of EWS-WWF, General Manager of WWNP during the period of the survey, Dr. Jacky Judas, Research Manager of WWNP, Maral K. Shuriqi of Fujairah Municipality, formerly also Operations Manager of WWNP, Binish Roobas of the Dubai Natural History Group, and Anniek Boshoven, formerly of Sharjah's Breeding Centre for Endangered Arabian Wildlife, for their assistance and their many courtesies, diligent observation and good companionship in the field, as well as their thoughtful comments and questions throughout the course of the survey. Best of all, the author has learned from each of them.

APPENDIX 1: An Annotated Checklist of the Flora of Wadi Wurayah National Park

by Gary R. Feulner

						H	A	B	I	T	A	T	S	
Family	**Genus**	**Species**	**Authority for Nomenclature**	**Growth & Form (refer to key at end)**	**Abund. (WWNP) (refer to key at end)**	**Pools**	**Wadi**	**Wadi Slope**	**Terrace**	**Terrace (Silt)**	**Gulley**	**Slope (Stony)**	**Slope (Rocky)**	**Remarks**
Ophioglossaceae	***Ophioglossum***	***polyphyllum***	A. Braun	p/f	R					1				Adder's tongue fern. Formerly eaten as a salad green (Jongbloed 2003). Single locality, all plants in silt accumulations; many in small plots representing long-abandoned cultivation in an improved natural gulley on gravel terrace above W. Wurayah waterfall. The record was in mid-December; no trace was seen at the same site in mid-March.
Pteridaceae	***Adiantum***	***capillus-veneris***	L.	p/f	C	1	1							Maiden's hair fern. Pendant at seeps on rock walls.
Pteridaceae	***Cheilanthes***	***acrostica***	(Balbis) Tod. sensu Jermy & Paul (1993)	p/f	R									Syn. *C. pteridioides*. Historical record from upper W. Siji (WWNP buffer zone) (by Curtis, 03/1998).
Pteridaceae	***Onychium***	***divaricatum***	(Poir.) Alston	p/f	O			1				1	1	Delicate digitate fern favouring sheltered sites among rocks on slopes. Fertile and infertile fronds have slightly different morphology.
Ephedraceae	***Ephedra***	***foliata***	Boiss. ex C.A. Mey.	p/sl	R		1	1	1					Syn. *E. ciliata*. One of only two UAE gymnosperms (the other is *E. pachyclada*, a high elevation species). Normally a climber or straggler, rarely a shrub. Five survey records: (1) straggler on a ledge and (2) shrub on a N-facing scree slope, both in mid-W. Ghayl; (3) shrub on open scree below low pass from Nimriyah area of W. Zikt (WWNP buffer zone); (4) straggler on a gravel wadi wall in upper W.Zikt; and (5) climber in top of a mostly dead ghaf tree in Powerline Wadi.
Arecaceae	***Phoenix***	***dactylifera***		p/h	R	1								Date palm. Self-seeded 'feral' plants at a few scattered locations within core zone, one below the abandoned settlement of Ghara in W. Ghayl. A few in upper Wadi Abadilah (WWNP bufferzone).
Cyperaceae	***Bolboschoenus***	**maritimus**	(L.) Palla	p/h	R									At water's edge beside pools at base of pipeline falls and along wadi above. A cosmopolitan species of warm, marshy environments. NB: The photos in Jongbloed (2003) are probably not *B. maritimus*. Problems of identification and lack of expert attention make it difficult to generalise confidently about the abundance and distribution of this and similar water-loving sedge spp. in the UAE (*Bolboschoenus* spp., *Fimbristylis* spp. and *Schoenoplectus littoralis*).
Cyperaceae	***Cladium***	***mariscus***	(L.) Pohl	p/sl	E	1								A few plants in standing water at base of pipeline falls – the sole UAE site for this large, water-loving species. Nearest site is at Jazirah oasis in Wadi Musayliq, Wilayat Mahdhah, Oman.

						H	A	B	I	T	A	T	S	
Family	Genus	Species	Authority for Nomenclature	Growth & Form (refer to key at end)	Abund. (WWNP) (refer to key at end)	Pools	Wadi	Wadi Slope	Terrace	Terrace (Silt)	Gulley	Slope (Stony)	Slope (Rocky)	Remarks
Cyperaceae	***Cyperus***	***conglomeratus***	Rottb.	p/h	R		1					1		A small number of scattered specimens: one in silt behind dam, others on scree at more remote sites, but including several in Dam Wadi. In the UAE, *C. conglomeratus* is primarily a species of sand deserts and is absent in most mountain areas. It is present nearby on an irrigated hillside at Suwaifah Park, Khor Fakkan, ca. 5 km from the mouth of Wadi Wurayah.
Cyperaceae	***Cyperus***	***rotundus***	L.	p/h	R	1								Small, delicate, at water's edge above waterfall, associated with *Bolboschoenus maritimus*; also along distal outflow from waterfall. Spikes very small, pedicelled. An invasive weed of the tropics and subtropics, per Boulos (2005).
Cyperaceae	***Schoenus***	***nigricans***	L.	p/ss	L	1								Beside small springs and pools at and above the roadhead pools in W. Wurayah. Rare in waterfall area.
Liliaceae	***Asphodelus***	***tenuifolius***	Cav.	a/e	H		1	1	1	1	2	2	2	Annual. Common (often hyperabundant) after rains in all environments.
Orchiadaceae	***Epipactis***	***veratrifolia***	Boiss. & Hohen.	p/h	R	1	1							A helleborine, the UAE's only orchid. Typical habitat is among *Adiantum capillus-veneris* at seeps on shaded rock walls. Also found among tall grasses and sedges at pools at base of pipeline waterfall.
Poaceae	***Aristida***	***abnormis***	Chiov.	a/g	O		1	1	1		1	1		Smaller than *A. adscensionis* and less common. Most specimens show little or no evidence of lateral awns.
Poaceae	***Aristida***	***adscensionis***	L.	a/g	L		1	1	1	2	1	1	2	A regionally widespread species, occasional in many environments at all elevations. Distinctive triple awns may not be readily apparent in early inflorescence. In young plants, centre of clump is often reddish.
Poaceae	***Arundo***	***donax***	L.	p/g	H	1	1							A very large reed, common where water table is high. Sometimes hyperabundant in lower wadis and may impede passage, as in Waterfall Branch. Striolated Bunting feeds on inflorescence.
Poaceae	***Brachypodium***	***distachyum***	(L.) P. Beauv.	a/g	L		1	1			1			More common than previously recognised.
Poaceae	***Bromus***	***danthoniae***	Trin.	a/g	E						1	1		Single record of dry plant from c.700m in uppermost W. Siji (WWNP buffer zone), near pass to W. Murtaqam This species is not included in Jongbloed (2003). Previously recorded only from Ru'us al-Jibal.

						H	A	B	I	T	A	T	S	
Family	Genus	Species	Authority for Nomenclature	Growth & Form (refer to key at end)	Abund. (WWNP) (refer to key at end)	Pools	Wadi	Wadi Slope	Terrace	Terrace (Silt)	Gulley	Slope (Stony)	Slope (Rocky)	Remarks
Poaceae	***Bromus***	***madritensis***	L.	a/g	R									Historical records (by Curtis) from W. Wurayah (03/1998) and from upper W. Siji (WWNP buffer zone) (03/1998). Survey record of several plants in upper W. Siji, ca. 0.5 km outside WWNP buffer zone.
Poaceae	***Castellia***	***tuberculosa***	(Moris) Bor	a/g	R		1							Single photo record from W. Ghayl. Historical record from upper W. Siji (WWNP buffer zone) (by Curtis, 03/1998). Multiple specimens recorded contemporaneously from a steep wadi bed draining the slopes of Jebel Qitab, SW of Fujairah city.
Poaceae	***Cenchrus***	***ciliaris***	L.	p/g	C		1	1	1		1	1	2	A common and widespread "bottlebrush" grass, growing in small clumps in diverse environments. Despite investigation, no other *Cenchrus* spp. were recognised.
Poaceae	***Cymbopogon***	***schoenanthus***	(L.) Spreng.	p/g	L		1	1	1		1	1	2	*Cymbopogon* spp., the source of citronella, are characterised by a basal clump of thin, curling leaves. Jongbloed (2003) lists a short, straight awn (with undifferentiated column) as the characteristic that distinguishes *C. schoenanthus* from *C. commutatus*. GRF has also taken note of its less robust and more splayed inflorescence (i.e., not so strongly recurved along the stem). But NB: Cope (2007) comments that while the distinction between *C. schoenanthus* and *C. commutatus* is straightforward in Africa, it is much more difficult in Arabia, where the most reliable diagnostic characters are arcane microscopic ones. Many specimens were inspected in the field during the survey and all were found to have a relatively short and undifferentiated awn, straight or bent, and a relatively loosely splayed, delicate inflorescence. Therefore only *C. schoenanthus* was recorded.
Poaceae	***Cynodon***	***dactylon***	(L.) Pers.	p/g	E					1				Weed in cultivated field beside upper W. Siji (WWNP buffer zone).
Poaceae	***Dichanthium***	***foveolatum***	(Delile) Roberty	p/g	R			1	1					Narrowly cylindrical inflorescence superficially resembles *Sporobolus spicatus* but long, dark awns distinguish it. Recorded only from roadhead parking area and above lower road crossing in W. Ghayl. Jongbloed (2003) does not recognise this species on the East Coast but GRF has also collected it in a peri-urban environment at Khor Fakkan.

						H	A	B	I	T	A	T	S	
Family	**Genus**	**Species**	**Authority for Nomenclature**	**Growth & Form (refer to key at end)**	**Abund. (WWNP) (refer to key at end)**	**Pools**	**Wadi**	**Wadi Slope**	**Terrace**	**Terrace (Silt)**	**Gulley**	**Slope (Stony)**	**Slope (Rocky)**	**Remarks**
Poaceae	***Digitaria***	***nodosa***	Parl.	p/g	L		1	1			1	1	1	All of the widespread, scattered specimens of *Digitaria* collected within WWNP are believed to be *D. nodosa*, consistent with the historical record of that species from Wadi Wurayah (by Curtis, 03/1998), which, however, remains the only prior UAE record. *D. nodosa* is an extremely variable species. Plant size in WWNP ranges from less than 50cm to more than 100cm. Spikelets are variable both in size (2.0-3.0mm) and surface texture (woolly to glabrous). Specimens collected during the baseline survey exhibit the full range of variation, but consistent features are the long and relatively conspicuous upper glume (almost the length of the spikelet) and (in most specimens) the presence of 1-2 distinct apical filaments. Spikelets of *D. nodosa* and other potentially relevant Digitaria species (*D. ciliaris*, *D. sanguinalis* and *D. velutina*) are depicted rather differently in illustrations in Boulos (2004) and Cope (2007), but keys in both of those references encourage primary reliance on the gross form of the plant, *D. nodosa* being distinguished as an erect, tufted perennial without rhizomes. Expert confirmation should nevertheless ideally be sought. [NB: Cope (2007) is sceptical of UAE and other Arabian records of *D. sanguinalis* but maps the only published record of *D. ciliaris* from the UAE's East Coast.]
Poaceae	***Echinochloa***	***crusgalli***	(L.) P. Beauv.	a/e	E					*				Field weed in single small field along upper W. Siji (WWNP buffer zone), at junction of route to W. Wurayah, 03/2014. Widespread warm temperate and subtropical weed.
Poaceae	***Enneapogon***	***desvauxii***	P. Beauv.	a/g	R			1						Single dry specimen from gravel terrace above Wadi Ghayl. A small 'bottlebrush' species, easily overlooked or mistaken.
Poaceae	***Enneapogon***	***persicus***	Boiss.	p/g	R						1			Multiple plants, probably related, along a single steep, rocky gulley. Prior records from Ru'us al-Jibal and Khor Fakkan only.
Poaceae	***Eragrostis***	***barrelieri***	Daveau	a/g	R		1		1					Two localities in WWNP buffer zone: one in fine gravel in HQ wadi, Jan 2014, with *E. cilianensis* and *E. ciliaris*; one on bank in upper W. Siji. Common on gravel plains and terraces on west flank of Hajar Mtns.
Poaceae	***Eragrostis***	***cilianensis***	(All.) Vign.	a/g	O		1	1	1					On gravel slope and terrace a month after moderate rain. Also HQ wadi (WWNP buffer zone) with *E. barrelieri* and *E. ciliaris*.

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Family	**Genus**	**Species**	**Authority for Nomenclature**	**Growth & Form (refer to key at end)**	**Abund. (WWNP) (refer to key at end)**	**Pools**	**Wadi**	**Wadi Slope**	**Terrace**	**Terrace (Silt)**	**Gulley**	**Slope (Stony)**	**Slope (Rocky)**	**Remarks**
Poaceae	***Stipagrostis***	***hirtigluama***	(Steud. ex Trin. & Rupr.) de Winter	p/g	L			1	2		2	2	1	ID per Boulos (2004) and Cope (2007). This appears to be the most common mountain species of *Stipagrostis* in the Hajar Mtns of the UAE and northernmost Oman, although the species found at higher elevations in the Ru'us al-Jibal is *S. raddiana* (= *S. paradisea*) (Feulner 2011). [NB: Western (1989) and Jongbloed (2003) both mapped *Stipagrostis plumosa* throughout the mountains of the East Coast, including the Ru'us al-Jibal, and El-Keblawy (2011) has recorded *S. plumosa* from Wadi Hiluw. *S. ciliata* is present in the Hajar Mountains in the Mahdhah area of Northern Oman. However, the author is aware of no determinations of material collected from WWNP, other than the multiple determinations of *S. hirtigluma* made in the course of the baseline survey. Scattered dried specimens collected in mid-May 2014 were anomalous: the central plumes were badly worn and tangled and the point of attachment of the lateral awns was extremely low, commencing within the glumes, often at or below the point of disarticulation. That pattern does not correspond to any other *Stipagrostis* spp. and the ciliate surface of the back of the glumes argues in favour of aberrant *S. hirtigluma*.]
Poaceae	***Tetrapogon***	***villosus***	Desf.	p/g	R						1	1		Few records from upper Wadi Siji (WWNP buffer zone), at elevations from wadi level up to pass to W. Murtaqam.
Poaceae	***Tricholaena***	***teneriffae***	(L.f.) Link	p/g	L		1	2			1			Widespread grass of the Eremic Zone. Favours areas of gravel wadi with higher water table.
Typhaceae	***Typha***	***domingensis***	Pers.	p/g	O	1								Requires standing water. Recognisable in seed by its "cattails". Also distinguished from other large UAE water plants by absence of spines on leaf margins.
Acanthaceae	***Blepharis***	***ciliaris***	L.	p/sd	O		2	1	1		1	1		Typical growth form is a cushion of long, fine spiny leaves, the central spine longer than the two lateral ones. Late flowering; most specimens dormant through March.
Aizoaceae	***Aizoon***	***canariense***	L.	p/p	C		1	2	1	1				Prostrate, spreading, with woody stems. Very common after rains.

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Aizoaceae	***Zaleya***	***pentandra***	(L.) C. Jeffrey	a/e-s	R		1							Single locality: HQ wadi (WWNP buffer zone), in fine gravel with other small annuals and grasses. Flowering in Jan 2014. ID by M. Jongbloed, confirmed per Miller & Cope (1996) and Boulos, Flora of Egypt. Plant is erect but very short (< 5cm), possibly grazed; leaves opposite, medium-dark green, ovate-lanceolate, with short pedicel, distinct centreline and widely spaced paired veins. Tiny red & white inflorescence in axial clusters. Capsule is a distinctive waxy, rectangular, red plug. Seeds are flattened ovoids, ~1.5 mm diameter, glossy black and (contrary to published descriptions) smooth.
Amaranthaceae	***Aerva***	***javanica***	(Burm. f.) Juss. ex Schult	p/sd	O		2	2	1					A ruderal species, occasional in mountain environments, especially formerly inhabited areas.
Anacardiaceae	***Mangifera***	***indica***	L.	p/t	E	1								The cultivated mango, an exotic species. Historical record (Feulner, 08/2009) of a seedling beside cement pipeline casing at edge of pool above waterfall, growing from a scraped and discarded mango pit.
Apocynaceae	***Nerium***	***oleander***	L.	p/sl	L	1	1							An indicator of subsurface water in the wadi bed. Generally found in association with temporary or permanent pools. NB: All parts of this plant are poisonous.
Apocynaceae	***Rhazya***	***stricta***	Decne.	p/sd	E						2			Single location, steep rubble gulley in upper W. Abadilah (WWNP buffer zone), a very atypical habitat for this species.
Asclepiadaceae	***Calotropis***	***procera***	(Aiton) W.T. Aiton	p/sl	R		2		2	2	2			Very common in the UAE generally, but not in mountain environments, where it is a rare and opportunistic coloniser of silty ruderal environments.
Asclepiadaceae	***Desmidorchis***	***arabicus***	(N.E. Br.) Meve & Liede	p/sd	O			2				1	1	Syn. *Caralluma arabica*. Endemic to mountains of UAE & N.Oman. Widespread but scattered. Tendency for several plants to be found in proximity. Foodplant for Plain Tiger caterpillars. More common at higher elevations.
Asclepiadaceae	***Glossonema***	***varians***	(Stocks) Benth. ex Hook. f.	p/sd	R		1				1	1		A small, semi-prostrate milkweed, widespread in the mountain environment at medium to high elevation, but almost always rare. Distinguished by its wrinkled, fleshy leaves. Large, warty, pickle-shaped fruit is unmistakeable. Only two specimens recorded in WWNP. Habitus among dwarf shrubs in W. Zikt suggests it may be eaten by browsers, but also found on open gravel slopes above W. Ghayl branch of W. Wurayah.
Asclepiadaceae	***Leptadenia***	***pyrotechnica***	(Forssk.) Decne.	p/sl	E		2			2				A large specimen of this common large desert shrub, along a track frequented by local residents, was probably inadvertently introduced. A second specimen, struggling but flowering, was found c.0.5km away, just above the lower road crossing in W. Ghayl.

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Asclepiadaceae	***Pentatropis***	***nivalis***	(J.F. Gmel.) D.V. Field & J.R.I. Wood	p/sl	R		2							A climbing species. Single plant recorded as straggler on wadi cliff in W. Ghalan fork of W. Yashimah.
Asclepiadaceae	***Pergularia***	***tomentosa***	L.	p/sd	L		1							A ruderal species that favours silty ground. Several plants in bed of shallow tributary wadi in upper Powerline Fork, Wadi Ghayl. Two plants near lower road crossing in W. Ghayl (one on bulldozed gravel). Several others in bulldozed depression beside car park for helicopter landings. Seen in flower in both January and July.
Asclepiadaceae	***Periploca***	***aphylla***	Decne.	p/sl	O						1	2	1	Erect, woody, leafless shrub. Favours cracks in rocky substrate.
Asteraceae	***Echinops***	***erinaceus***	Kit Tan	p/sd	O		1	1			1	1	2	Endemic to mountains of UAE & N.Oman. The Hajar Mtn "*Echinops* sp." of Jongbloed (2003) has recently been provisionally diagnosed as *E. erinaceus* (see Feulner 2011). Favours scree and loose gravel. Most often seen as basal rosette only.
Asteraceae	***Filago***	***desertorum***	Pomel	a/p	O		2	1			1			Locally common on descent from W. Siji pass to W. Murtaqam; single plant in wadi gravel in picnic area below waterfall. Also occasional in upper W. Siji (WWNP buffer zone) on ascent route to pass. UAE records of this species are rare outside Ru'us al-Jibal.
Asteraceae	***Filago***	***pyramidatum***	L.	a/e	R		2							Few records from upper W. Siji, c.450-600m (WWNP buffer zone) where *F. desertorum* also present. A rare mountain species (Jongbloed 2003, Feulner 2011). Distinguished from *F. desertorum* chiefly by its erect habit and branched stems.
Asteraceae	***Helichrysum***	***glumaceum***	DC.	p/sd	O		2				1	1		Syn. *H. makranicum* (see Feulner 2011). Scattered solitary plants, somewhat more common at higher elevation. In Ru'us al-Jibal, at higher elevations only.
Asteraceae	***Ifloga***	***spicata***	(Forssk.) Sch. Bip.	a/e	R		1		1		2	1	2	Small but distinctive annual. Few scattered specimens. Also historical records from W. Yashimah and upper W. Siji (WNPP buffer zone).
Asteraceae	***Iphiona***	***scabra***	Decne.	p/sd	O		2	1	1					Needle-sharp spines are arranged in cones; individual spines are barbed. More common at higher elevation.
Asteraceae	***Launaea***	***bornmuelleri***	(Hausskn. ex Bornm.) Bornm.	p/sd	O						1	1	1	Formerly mistakenly ID'd as *Launaea spinosa*. Readily identifiable by zig-zag stem growth and overall cushion-like form. Slopes at higher elevations. Browsed.
Asteraceae	***Launaea***	***capitata***	(Spreng.) Dandy	a/p	O		1	1	1	1				Prostrate basal rosette with central or trailing inflorescence. Survey records other than from silt behind Wurayah Dam were based on ID of basal rosette.

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Asteraceae	***Launaea***	***massauensis***	(Fresen.) Sch. Bip. ex Kuntze	a/e	L		2	1	1		2	1	2	Erect but delicate inflorescence is unmistakeable. When not in flower, can be identified (with experience) by the very large dissected leaves of the basal rosette, which have rounded tips.
Asteraceae	***Launaea***	***omanensis***	Kilian	p/h	R		1				1	1		Endemic to Hajar Mtns of UAE & N.Oman. Several scattered plants, one (flowering 03/2013) in small scree gulley at Ghalil al-Haban, others in tributaries of W. Ghayl: one in wadi bed of third-order tributary, two flowering 03/2014) in shallow gulleys on terraces. Very similar to *L. nudicaulis*, distinguished by greyish blue-green stems and distinctive buds. Photo ID by Norbert Kilian.
Asteraceae	***Launaea***	***procumbens***	(Roxb.) Ramaya & Rajogopal	p/h	E		1							Single plant flowering beside stream at picnic area below waterfall.Photo ID by Norbert Kilian.
Asteraceae	***Pentanema***	***divaricatum***	Cass.	a/e	E				1					Single historical record (by Feulner, 3/1997, as *Vicoa pentanema*) on terraces in W. Zikt. The author was familiar with the species from the Ru'us al-Jibal, but this is the only known record outside the Ru'us al-Jibal.
Asteraceae	***Phagnalon***	***schweinfurthii***	Sch. Bip. ex Schweinf.	p/sd	E						1			Syn. *P. viridifolium* (see Feulner 2011). Heavily browsed, therefore most common where inaccessible or protected. Only two small plants seen at single location, at c.200m in gulley on slope in lower W. Ghayl. Elsewhere in UAE, generally found only at higher elevations. Historical record from upper W. Siji (WNPP buffer zone) (by Curtis, 03/1998). Recognisable even when grazed, by the elongated, slightly clasping attachment of the dark green leaves to the white stems.
Asteraceae	***Pulicaria***	***edmondsonii***	Gamal-Eldin	p/sd	L		2				2	1	1	Endemic to UAE & N.Oman (Hajar Mtns and Ru'us al-Jibal). Locally common along high gulleys. Occasional seedlings in wadi beds.
Asteraceae	***Pulicaria***	***glutinosa***	(Boiss.) Jaub. & Spach	p/sd	O		1	2	1		1	2		Occasional in terrace environments, including gentle, rolling stony slopes. Common in wadis and on terraces on west flank of Hajar Mtns.
Asteraceae	***Reichardia***	***tingitana***	(L.) Roth	a/p	C		1	1	1	1	2			Dark yellow flower (± red centre) is a cup-like spray of petals set in a prostrate basal rosette of finely toothed leaves.
Asteraceae	***Senecio***	***breviflorus***	(Kadereit) Greuter	a/e	O		1	1			1	1		Late flowering (seen only in March). Recognisable by its clasping leaves, which are usually purple on the underside, even as seedlings. *S. breviflorus* has been distinguished from *S. flavus*, a Mediterranean species, with which it was conflated in earlier UAE literature (see Feulner 2011).
Asteraceae	***Sonchus***	***oleraceus***	L.	a/e	R		1							A ruderal species of silty env'ts, recorded in silt behind dam and picnic area below waterfall.

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Asteraceae	***Vernonia***	***arabica***	F.G. Davies	p/sd	O		2	1			1	1	2	Pale silvery-green leaves and stems. Typical habitat is stony slopes and gulleys. More common at higher elevations. Seedlings may show 5-pointed leaves (versus 3-pointed). Rarely, mature plants may show oval leaves, without lateral points.
Asteraceae	***Zoegea***	***purpurea***	Fresen.	a/e	O		1	1			1	1		Late-flowering. Not seen until early March but past flower by June.
Boraginaceae	***Anchusa***	***aegyptiaca***	(L.) DC.	a/p	R		1							Single plant in gravel wadi bed in upper W. Siji (WWNP buffer zone), near fallow cultivated field.
Boraginaceae	***Arnebia***	***hispidissima***	(Lehm.) DC.	a/e	L		1	1	1	1	2	2		Flowered during winter 2011-12 and 2012-13, after fall rains, but dry by March.
Boraginaceae	***Echiochilon***	***persicum***	(Burm. f.) I.M. Johnst.	p/sd	R						1			Historical record of single plant on traverse from upper W. Siji (WWNP buffer zone) to W. Murtaqam (by Feulner, 12/1995). Widespread but rare in Hajar Mtns generally.
Boraginaceae	***Heliotropium***	***brevilimbe***	Boiss.	p/sd	C		2	1	1		2	1		Syn. *H. calcareum.* A characteristic species of gravel terraces. In flower, unmistakeable as the "octopus plant"; elongated racemes with paired flowers resemble cephalopod tentacles.
Boraginaceae	***Lappula***	***spinocarpos***	(Forssk.) Asch. ex Kuntze	a/e	O		2							Few plants in wadi gravel in upper W. Siji (WWNP buffer zone). ID is provisional due to possibility of confusion with *Ogastemma pusillum.*
Boraginaceae	***Paracaryum***	***intermedium***	(Fresen.) Lipsky	a/e	R		1	1						Few small plants in shade in wadi bed in upper W. Siji (WNPP buffer zone). This species is seen only in rainy years. Post-report photo reord from terrace near parking area at end of paved road.
Boraginaceae	***Trichodesma***	***enetotrichum***	R.R. Mill.	p/sd	O		1	1			1			Leaves are distinctive: stiff, tubercular and bristly. Buds and flowers also distinctive.
Brassicaceae	***Diplotaxis***	***harra***	(Forssk.) Boiss.	a/e	C		1	1	1		1	1	1	Although absent in December 2012 and with only occasional seedlings in January 2013, it was common and in flower by March 2013.
Brassicaceae	***Morettia***	***parviflora***	Boiss.	p/sd	O		1	1	1					Favours gravel substrate. 1-2 plants recorded on each of several terraces.
Brassicaceae	***Notoceras***	***bicorne***	(Aiton) Amo	a/p	R		2		1					Single specimen in flower in mid-wadi bed, W. Zikt (by Feulner, 01/2012). Typical habitat is gravel terraces.
Brassicaceae	***Physorrhynchus***	***chamaerapistrum***	(Boiss.) Boiss.	p/sd	O		1	2	1	1				Favours silt in wadi beds, banks or terraces.
Brassicaceae	***Sinapis***	***arvensis***	L.	a/e	R		1							Wild mustard. Two specimens (one >1m tall) flowering in silt in dam basin, Jan 2014.

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Brassicaceae	***Sisymbrium***	***erysimoides***	Desf.	a/e	O		1	1			1			Favours shaded or sheltered sites, usually among other annuals. A very similar congener, *S. irio*, was mapped by Jongbloed (2003) throughout the Hajar Mountains of the UAE, but as "uncommon". In the course of the baseline survey, in most instances no attempt was made to distinguish between the two *Sisymbrium* spp., but the occasional fruits that were examined all appeared to be *S. erysimoides*. Both species were recorded from Wadi Hiluw by El-Keblawy (2011). *S. erysimoides* was found there in both natural habitats and plantations; no habitat information is given for *S. irio*. According to Jongbloed (2003), the two species can be distinguished by the shape of the fruits and their stalks, and by the colour of the seeds within.
Campanulaceae	***Campanula***	***erinus***	L.	a/e	E		2							Single plant in wadi gravel near base of pipeline waterfall. Historical record from upper W. Siji (WNPP buffer zone) (by Curtis, 03/1998). Single plant also recorded from slopes of J. Qitab, SW of Fujairah. Otherwise known only from Ru'us al-Jibal, where it favours sheltered sites.
Capparaceae	***Capparis***	***spinosa***	L.	p/sd	O		1						1	Source of the edible European caper. Favors ledges or cliffsides, possibly because it is edible. Flowers (seen in March) attract butterflies. Association suggests it may be a food plant of the Salmon Arab.
Capparaceae	***Cleome***	***austroarabica***	Cham. & Lam.	p/sd	O	1	1							Dense, grey-green; leaves finely bristled but not aromatic or sticky.
Capparaceae	***Cleome***	***noeana***	Boiss.	a/e	L		1							Erect, yellow-green stems with ascendent seed pods. Distinctively aromatic and sticky. A ruderal/wadi bed species. Locally common upstream of W. Wurayah dam, few elsewhere.
Capparaceae	***Cleome***	***rupicola***	Vicary	p/sd	O		1	1	1		1			Erect, yellow-green stems, pendant seed pods.
Capparaceae	***Cleome***	***scaposa***	DC.	a/e	R		2	2						Historical record from single locality in upper W. Abadilah (by Feulner, 10/2003), on rubble slope and gravel wadi wall. Small plant with stiff, spade-shaped, glandular oval leaves. Normal habitat is gravel plain or terrace. WWNP is at or near the northern extent of its range. More common in interior Northern Oman.
Caryophylla-ceae	***Cometes***	***surattensis***	L.	p/sd	O		2	1				1	1	Small cushion of smooth, blue-green oval leaves. Favours rocky sites. Late developing; much more common in March than in January.
Caryophylla-ceae	***Dianthus***	***crinitus***	Sm.	p/h	E							1		Single location. Two specimens (only) on scree slope in upper Dam Wadi (North), below granite dike, c.500m. Rare outside high elevations in Ru'us al-Jibal.
Caryophylla-ceae	***Gymnocarpos***	***decandrus***	Forssk.	p/sd	L		2	2	1		1	1	2	Intricately twisted grey-brown branches with dark green worm-like leaves, turning reddish when dry. Inconspicuous yellow-green flowers. Especially common at base of stony slopes above terraces.

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Caryophylla-ceae	***Gypsophila***	***bellidifolia***	Boiss.	a/e	O		1	1						Widespread in wadi gravel.
Caryophylla-ceae	***Paronychia***	***arabica***	(L.) DC.	a/p	O		1							Scattered records of single plants, usually in wadi gravel. WWNP records extend the range shown in Jongbloed (2003), which was limited to the west flank of the Hajar Mtns.
Caryophylla-ceae	***Polycarpaea***	***robbairea***	(Kuntze) Greuter & Burdet	a/p-s	O		1	1	1		2			On medium to fine gravel of wadi beds or terraces.
Caryophylla-ceae	***Sclerocephaus***	***arabicus***	Boiss.	a/s	E		1	1			1	1		Historical record of single plant from upper W. Siji (WWNP buffer zone) (by Feulner, 12/1995). Locally common on west flank of Hajar Mtns, especially at J. Qatar, Wilayat Mahdhah, Oman (carbonate rock) (02/2013).
Caryophylla-ceae	***Silene***	***austro-iranica***	Rech. f., Aellen & Esfand.	a/e	C		1	1			1	1		Unexpectedly common in diverse habitats. Flowered early March through early June. Identifiable when not in flower by faint reddish sticky patches on stem, between leaf nodes.
Caryophylla-ceae	***Spergula***	***fallax***	(Lowe) E.H.L. Krause	a/e	O		1	1			1			Diminutive plant with villous leaves in whorls. Generally favours sheltered habitats, often among other annuals.
Caryophylla-ceae	***Spergularia***	***diandra***	(Guss.) Boiss.	a/e	R		1							Single specimen in bud in W. Ghayl just above lower road crossing, among other annuals. Provisional ID per Boulos, *Flora of Egypt*. Leaves opposite, not in whorls.
Chenopodaceae	***Chenopodium***	***murale***	L.	a/e	O		1	1	1	1				Ruderal species seen at donkey resting sites and formerly inhabited terraces. Probably facilitated by man and domestic animals.
Chenopodaceae	***Haloxylon***	***salicornicum***	(Moq.) Bunge ex Boiss.	p/sd	R		1							Single historical record (by Feulner, 01/2012) from lower W. Zikt (WWNP buffer zone). One of the most common and widespread species in the UAE generally, but very rare in mountain environments. Typical habitat is sandy plains.
Chenopodaceae	***Suaeda***	***aegyptiaca***	(Hasselq.) Zohary	a/s	E		2							Three records only: one from silt behind W. Wurayah dam; one from silt in wadi gravel in W. Ghayl, below Ghara; and one from waterfall picnic area. Unusual in mountain environments.
Cistaceae	***Helianthemum***	***lippii***	(L.) Dum. Cours.	p/sd	O			2	1		1	1		Only a few scattered small plants recorded, mostly on terraces or slopes, but one on bank of shallow tributary in upper Powerline Wadi. In Ru'us al-Jibal, more common at higher elevations.
Convolvulaceae	***Convolvulus***	***glomeratus***	Choisy	p/sd	O			1	1		1	1		Erect, grey-green, less robust than *C. virgatus*. Sepals are hirsute but not fuzzy. Narrow lanceolate leaves not recurved along stem. Flowers white with distinct a pinkish rib on the underside of each of the fused petals. NB: Photo in Jongbloed (2003) is not *C. glomeratus*.

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Convolvulaceae	***Convolvulus***	***virgatus***	Boiss.	p/sd	C		1	1	1		1	1	2	The most common mountain *Convolvulus*. Conspicuous in flower. Flowers (white to pinkish) and leaves variable, especially new growth after rain. Narrow lanceolate leaves strongly to weakly recurved along stem. Hairy sepals surround flower and seed in pinkish-grey fuzz. Flowers do not have distinct, coloured ribs on the underside. Notwithstanding its abundance, this is a favourite species of browsers and is often grazed to a cushion where they are present. In WWNP, this was seen in upper W. Ghulayyil Khun (WWNP buffer zone).
Convolvulaceae	***Cuscuta***	***planifora***	Ten.	a/s	O		1	1	1	1				Spreading parasite usually found on low annuals, e.g., *Arnebia hispidissima*, *Asphodelus tenuifolius*, *Fagonia brugueri*, *Plantago* spp. Rare except after rain; usually found as multiple localised plants.
Cucurbitaceae	***Citrullus***	***colocynthis***	(L.) Schrad.	p/p	L		1							Prostrate, straggling, with tennis ball sized melon-like fruits. Hyperabundant in silt behind dam, where fruits collect as flotsam.
Cucurbitaceae	***Citrullus***	***lanatus***	(Thunb.) Matsumura & Nakai	p/p	E		2							Cultivated watermelon, found as an exotic at the picnic area below waterfall; also several flowering plants just above lower road crossing in Wadi Ghayl.
Cucurbitaceae	***Cucumis***	***prophetarum***	L.	p/p	O		1	1	1		2			Prostrate, straggling and bristly, with small, spiny melon-like fruits. Seeds may be spread in part by animals (donkeys *et al.*).
Euphorbiaceae	***Andrachne***	***aspera***	Spreng.	p/sd	O		1	1			1			Many plants were examined and/or collected in an effort to distinguish possible *A. telephioides*, but all were determined to be *A. aspera* on the basis of numerous characteristics listed in Jongbloed (2003) and Ghazanfar (2007), although many had leaf petioles up to 0.3mm. This is consistent with the more south-westerly range shown for *A. telephioides* in Jongbloed (2003).
Euphorbiaceae	***Chrozophora***	***oblongifolia***	(Delile) Spreng.	p/sd	L		1							Common in the silty basin for c.1km above Wurayah dam but only a few scattered records elsewhere. On west flank of Hajar Mtns it is common in lower wadis and in summer is an important flowering species for butterflies.
Euphorbiaceae	***Euphorbia***	***arabica***	Hochst. & Steud. ex Boiss.	a/e	L		1	1			1			Delicate, erect. Resembles an elongated, diffuse, erect version of the prostrate *E. granulata*. Flowered in Dec-Jan, soon after fall rains.
Euphorbiaceae	***Euphorbia***	***granulata***	Forssk.	a/p	O		2		1					Few records within core zone, mostly from gravel terraces along W. Ghayl. Locally common at WWNP HQ. Historical records (by Feulner) from W. Ghayl, W. Zikt and WWNP buffer zones (upper W. Siji and upper W. Abadilah).

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Euphorbiaceae	***Euphorbia***	***larica***	Boiss.	p/sl	C			2	1	1	1	1	2	Leafless, pale yellow-green shrub is a prominent component of hillside vegetation. Shallow, spreading roots are quick to capture rain. Dead plants collapse in a distinctive ring pattern. Disintegration creates open silt patches on terraces.
Fabaceae	***Argyrolobeum***	***roseum***	(Camb.) Jaub. & Spach	a/p	C		1	1	1		2	2		On gravel. Leaves trifoliate, each with deep centreline.
Fabaceae	***Astragalus***	***fasciculifolius***	Boiss.	p/sl	R						1		1	Most records are historical: rare shrubs in upper W. Murtaqam (by Feulner, 12/96); shrubs on slopes in uppermost W. Zikt, SW Branch (by Feulner, 3/1997); and few shrubs in the latter area, near pass in granitic dike, c.700m (by Feulner, 01/2012). During the baseline survey, one seedling and two shrubs (including one flotsam top) were found at wadi level in tributaries of the same branch of W. Zikt. Hornby (1996) also mentions this species. Otherwise known only from Ru'us al-Jibal and isolated records from Olive Highlands, SW of Fujairah city.
Fabaceae	***Crotalaria***	***aegyptiaca***	Benth.	p/sd-sl	O		1	1						Widespread grey-green, erect shrub. Typical habitat is gentle wadi banks.
Fabaceae	***Hippocrepis***	***constricta***	Kunze	a/e	O		1	1	1					Small, delicate. Readily ID'd by flower or seed pod.
Fabaceae	***Indigofera***	***coerulea***	Roxb.	p/sd	R		1							Single plant in seed in Ghara tributary of Powerline Fork, 10/01/15; low, spreading, ca. 75cm wide.
Fabaceae	***Lotononis***	***platycarpa***	(Viv.) Pic.-Serm.	a/p	L		2		1	1				Inconspicuous pale green prostrate distinguished by its distal trident of oblong leaves. Flowered in Dec-Jan after autumn rains but absent in March.
Fabaceae	***Lotus***	***schimperi***	Steud. ex Boiss.	a/p	E		1							Single plant in silt/gravel at picnic area below waterfall.
Fabaceae	***Medicago***	***laciniata***	(L.) Mill.	a/e	R			1						Few plants in silt on slope beside upper W. Abadilah (below pass to W. Yashimah) (WWNP buffer zone). Possibly spread from cultivated fields lower in W. Abadilah.
Fabaceae	***Pseudolotus***	***makranicus***	(Rech. f. & Esfand.) Rech. f.	a/p	O		1	1	1		1	1		May be synonymised with *P. villosus*. Seen only in W. Zikt (few plants scattered along gravel wadis, in flower in 06/2013) and Powerline Fork of W. Ghayl (common in flower and seed in 03/2014). Favors medium gravel habitats.
Fabaceae	***Rhynchosia***	***minima***	(L.) DC.	p/sd	E		1							Historical record from upper W. Abadilah (by Feulner, 10/2003), next to pool w/ *Typha domingensis*. Very rare in northernmost Hajar Mtns and Ru'us al-Jibal; locally common at single locality in SE Ru'us al-Jibal.
Fabaceae	***Senna***	***italica***	Mill.	p/sd	O		1							Syn. *Cassia italica*. Scattered plants in silt in flat gravel wadis.
Fabaceae	***Taverniera***	***cuneifolia***	(Roth) Arn.	p/sd	O		2	1	2		1	1	2	Syn. *T. glabra*. Somewhat more common on lower slopes above tributary wadis and terraces.

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Fabaceae	***Tephrosia***	***apollinea***	(Delile) DC.	p/sd	C		1	1			2			Favours silt among stony wadi beds and banks. More common in lower wadis. Unpalatable to browsers but flowers are a favourite of butterflies. All specimens collected by the author in the Hajar Mtns and Ru'us al-Jibal have been ID'd by L. Boulos as *T. purpurea* (L.) Pers. subsp. *leptostachya* Brummitt. The differences between *T. purpurea* and *T. apollinea* are minimal and some experts believe that they should be treated as conspecific (Ghazanfar 2007). They were not distinguished by the author in the field. The use of *T. apollinea* here follows Western (1989) and Jongbloed (2003), the two best-known comprehensive floras of the UAE; the plant is well known to UAE naturalists by that name.
Fabaceae	***Tephrosia***	***cf. uniflora***		p/p	E		1							In mid-February 2013, a single small, spreading specimen of *Tephrosia* with pale pink, solitary axial flowers and a small cluster of distal flowers was found in silt behind W. Wurayah Dam, where it was called to the author's attention by Mme. Frederique Combreau. Much later, in mid-May 2014, two small, diffuse plants which appear to represent the same species were observed in the bed of Wadi Dhahir. The sabre-shaped pods are similar to *T. apollinea* (itself a difficult taxon) but the flowers and habit argue in favour of regarding it as a separate species. *T. uniflora* Pers. is the closest match among the regional *Tephrosia* spp. described in Boulos (1999), Jongbloed (2003) and Ghazanfar (2007). *T. uniflora* has been recorded from Al-Ain by Jongbloed (2003) and from W. Hiluw by El-Keblawy (2011) (whose photo resembles the W. Wurayah specimen), although it is not among the *Tephrosia* spp. treated in Ghazanfar (2007). Features consistent with *T. uniflora* include: (i) small number of leaflets (3-7); (ii) presence of individual axial flowers on very short pedicels; (iii) flower colour is relatively pale pinkish-purple; (iv) whole plant (including stems, leaves, bracts and ribs of pods) is covered with sparse, silky, semi-appressed hairs, vs. short, dense, erect, bristly hairs in specimens of *T. apollinea* from WWNP; (v) paired stipules at axils are thin, short (to c.3mm), stiff, awl-like and often spreading, vs. longer (to c.5mm), flattened, bladelike and ascending in *T. apollinea*. In addition, the leaves are uniformly narrower and the sepals are much less densely hairy than for *T. apollinea*.
Gentianaceae	***Centaurium***	***pulchellum***	(Swartz) Druce	a/e	R		1							Single survey record from beside waterfall picnic area, among sheltering vegetation. Also historical record from upper W. Siji (WWNP buffer zone) (Feulner, 03/1998).

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Geraniaceae	***Erodium***	***neuradifolium***	Delile	a/p-s	O		1	1			1			All of a number of specimens collected in seed from various sites proved to be *E. neuradifolium*, per Boulos (*Flora of Egypt*), Ghazanfar (2007) and Karim & Fawzi (2007). Three other *Erodium* species have been recorded from the UAE (Jongbloed 2003) and could potentially be present. Determination requires examination of the individual fruiting parts under magnification. Leaves and growth habit seem to be poor guides.
Geraniaceae	***Geranium***	***biuncinatum***	Kokwaro	a/s	O		1	1		1	1			Sheltered damp sites with silt. *G. biuncinatum* is readily distinguished by the paired curved "horns" on its beaked seed capsules. The most common and widespread *Geranium* species present in WWNP during the survey.
Geraniaceae	***Geranium***	***trilophum***	Boiss.	a/s	O		1	1		1	1			Sheltered damp sites with silt. Determination based on the strongly toothed, three-keeled mericarp. Collected within a few hundred metres of *G. biuncinatum*; also from upper W. Siji (0.5 km downstream from WWNP buffer zone).
Geraniaceae	***Monsonia***	***cf. heliotropioides***	(Cav.) Boiss.	a?/e	R		2		2					Recorded from silt above dam and parking area at head of paved road. Possibly anthropogenic but also seen on East Coast on slopes of J.Qitab, SW of Fujairah city. Resembles *M. heliotropioides* in having sepals tipped with a purple mucro and relatively short petals, but mericarp does not resemble either *M. heliotropioides* or *M. nivea* as shown in Boulos (*Flora of Egypt*). Instead, the mericarp features a pit and furrow resembling that of *Erodium neuradifolium*, but with a weak septum dividing the pit. The possibility exists that this is a species from the Makran that has not yet been recognised in the UAE or Northern Oman.
Lamiaceae	***Lavandula***	***subnuda***	Benth.	p/sd	C		1	1	2		1	1	1	Often found at base of slopes or ledges, including edge of wadis. Flowers on racemes bloom serially, so that one or more is normally in flower.
Lamiaceae	***Leucas***	***inflata***	Benth.	p/sd	C		2	1	2		1	1	2	Erect stems; opposite leaves with blunt scalloped apex; evenly spaced whorls of flowers and seeds. Common in WWNP relative to other Hajar Mtn areas.
Lamiaceae	***Salvia***	***aegyptiaca***	L.	a/e	O		2	1	2		1	1	1	Many specimens observed during the survey were seedlings (basal rosettes) in the wadi bed or adjacent gravel bank, although elsewhere this species is primarily a higher elevation mountain plant. Late flowering. It is edible and could suffer from selective grazing.
Lamiaceae	***Salvia***	***macilenta***	Boiss.	p/sd	R				2		1			Widespread but rare woody perennial, mostly single plants. Cluster of several plants in side gulley of W. Aqabat. Browsed. WWNP records are among the northernmost. Records are somewhat more frequent from wadis in the Mahdhah area of Oman.

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Lamiaceae	***Salvia***	***macrosiphon***	Boiss.	a/e	O		1	1			1	1		Scattered single plants, mostly seen as basal rosettes of large, tongue-textured leaves.
Lamiaceae	***Satureja***	***imbricata***	(Forssk.) Briq.	p/h	R						1		1	Syns. *Micromeria biflora*, *M. imbricata*. Historical records from W. Zikt (by Feulner, 01/2012) and upper W. Siji (WWNP buffer zone) (by Curtis, 03/1998).
Lamiaceae	***Teucrium***	***stocksianum***	Boiss.	p/sd	R		1				1	1		Only five plants recorded, at three localities: one on rocky slope in upper Dam Wadi (North), below granite dike, c.550m; two adjacent plants in a steep gulley in lower Powerline Fork of W. Ghayl; and two scattered plants beside shallow tributary of upper Powerline Fork (where more are considered likely). Latter records are anomalously low elevation. Rarity in WWNP was unexpected. Occasional at higher elevations in Ru'us al-Jibal and Hajar Mtns south of Hatta.
Linaceae	***Linum***	***corymbulosum***	Reichb.	a/e	O							1	1	Higher elevations only (350m at Blue Water Pass and >600m at pass between W. Murtaqam and W. Siji). Flowering in mid-March.
Malvaceae	***Hibiscus***	***micranthus***	L.	p/sd	O		1	1			1	1		Erect, woody stems, orange bark, dark green leaves. Not seen at higher elevations. Preferentially browsed (by sheep) in upper W. Ghulayyil Khun (WWNP buffer zone), where it is typically seen growing within the protection of a larger, inedible shrub.
Malvaceae	***Malva***	***parviflora***	L.	a/p	R		1			1				Single historical record from wadi bed of W. Zikt (by Feulner, 01/2012).
Menispermaceae	***Cocculus***	***pendulus***	(J.R & G. Forst.) Diels	p/sl	O		1	1	1				1	The most common hanging or climbing species in W. Wurayah. Leaves variable: oblong (rarely oval) to unequal three-lobed.
Mimosaceae	***Acacia***	***ehrenbergiana***	Hayne	p/t	L		1							Single locality at HQ area (WWNP buffer zone), in wadi and terrace gulleys, shrub to tree-size. Normally has multiple stems at ground level. Leaves have only 1-2 pairs of pinnae; flowers yellow.
Mimosaceae	***Acacia***	***tortilis***	(Forssk.) Hayne	p/t	C		2	1	1		1	2	2	Most common tree species of the Hajar Mtns.
Mimosaceae	***Prosopis***	***cineraria***	(L.) Druce	p/t	R		1							Two individual trees (one at terminus of track in main wadi), plus a grove of ca. one dozen trees in W. Ghayl, below the abandoned settlement of Ghara. Distribution suggests human facilitation.
Moraceae	***Ficus***	***cordata salicifolia***	Thunb. subsp. salicifolia (Vahl) C.C. Berg	p/t	C		1	2						Typical situs is at or near base of wadi walls.
Moraceae	***Ficus***	***johannis***	Boiss.	p/t	R			2					1	UAE's only deciduous native tree. White bark. Normal leaves broadly three-lobed; grazed leaves smaller and narrowly tri-digitate. Usually found only at higher elevations (e.g., Ghalil al-Haban and uppermost W. Yashimah) but at least two specimens were recorded at or near wadi level within 2 km below the waterfall.

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Moraceae	***Ficus***	***religiosa***	L.	p/t	E	1								The *peepul* tree, an exotic species. Single seedling growing from woody rootstock on cement pipeline casing at edge of pool just above waterfall. This plant may have been dislodged by flooding on 01/11/14.
Moringaceae	***Moringa***	***peregrina***	(Forssk.) Fiori	p/t	C		1	1			1	1	1	Common on Hajar Mtn slopes. Favours scree, rubble, ledges and cliffs. Seedling very unlike adult, resembles Fabaceae, and may be found in wadi bed environments where adults are unlikely to thrive.
Nyctaginaceae	***Boerhavia***	***elegans***	Choisy	p/sd	O		1	1	1		1	1		Delicate, erect, dark pink inflorescence (tiny flowers on long stems) is unmistakeable. Basal leaves elliptical with dark pink margin. More common in wet years.
Orobanchaceae	***Orobanche***	***cernua***	Loefl.	a/e	R						1	1		A parasite found at higher elevations. Recorded only below pass in Blue Water Wadi (tributary of W. Ghayl), where several specimens were present in early March. Historical record from upper W. Siji (WNPP buffer zone) (by Curtis, 03/1998).
Papaveraceae	***Papaver***	***decaisnei***	Hochst. & Steud. ex Elkan	a/e	R		1							Few specimens in flower photo'd by C. Tourenq, 17/03/2006 (as *P. dubium*), probably from WWNP. The environment (harzburgite gravel) and the timing (contemporaneous with an EWS-WWF plant survey) are indicative. Nomenclature used here follows Ghazanfar (*in prep.*) and Feulner (2011).
Plantaginaceae	***Plantago***	***afra***	L.	a/e	O		1	1			1	1	1	Not seen until March. More common than other *Plantago* spp. in steeper environments.
Plantaginaceae	***Plantago***	***amplexicaulis***	Cav.	a/s	L		2	1	1		1	1		Flowering in January; dry by June.
Plantaginaceae	***Plantago***	***ciliata***	Desf.	a/p	C		1	1	1	1	1	1		Favours open silt in diverse environments. Some in flower in January.
Plantaginaceae	***Plantago***	***ovata***	Forssk.	a/p	L				1	1	1	1		Favours gravel terraces. The only *Plantago* sp. recorded in December; locally common in January but uncommon thereafter.
Plumbaginaceae	***Dyerophytum***	***indicum***	(Gibs. ex Wight) Kuntze	p/sl	C		1	2			1	2	1	Most common large shrub in W. Wurayah. Wrinkled, salt-encrusted leaves. Stems appear to penetrate the proximal ends of leaves. Favours walls and slopes.
Polygalaceae	***Polygala***	***erioptera***	DC.	a/e	O		1	1		1	1	1		Can be mistaken for *Convulvulus* seedlings when not in flower or seed. Stems rigid, grey-green; thin, elongated leaves have blunt rounded tip. Some flowers in both December 2013 and January 2014.
Polygonaceae	***Pteropyrum***	***scoparium***	Jaub. & Spach	p/sd-sl	C		1	1	2		2			Endemic to mountains of UAE & N.Oman. Favours substrate of coarse cobbles or gravel with silt, but also found on rocky slopes near gulleys. Twisted, fibrous, grey-brown branches with med-dark green worm-like leaves.

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Polygonaceae	***Rumex***	***limoniastrum***	Jaub. & Spach	p/sd	R		2	1						Endemic to UAE & N.Oman (Hajar Mtns and Jebel Akhdar). Erect to semi-pendant with fleshy, yellow-green, blade-shaped leaves, resembling a caper w/o spines. Typically found on ledges, walls or other sites protected from browsing. Widespread but very rare – after its collection by Aucher-Eloy in the Jebel Akhdar in 1837, it was not recorded again until the 1990s, when it was observed by Feulner at several sites in the UAE and northernmost Oman and ID'd by Curtis (1999). Two WWNP records, one from upper W. Zikt and one (historical) from upper W. Siji (WWNP buffer zone) by Curtis. Records are somewhat more frequent from the mountains S of Hatta.
Polygonaceae	***Rumex***	***vesicarius***	L.	a/e	H		1	1	2	2	1	2		Hyperabundant after rain in well-drained substrate, but slow to flower.
Primulaceae	***Anagallis***	***arvensis***	L.	a/e	H		1	1			1	1		Hyperabundant in silt accumulations among rocks, especially in sheltered environments.
Primulaceae	***Asterolinon***	***linum-stellatum***	(L.) Duby	a/e	R			1						Single site on medium gravel of north facing wadi bank, among other annuals. Otherwise not recorded outside Ru'us al-Jibal. Easily overlooked and possibly under-recorded.
Resedaceae	***Ochradenus***	***arabicus***	Chaudhary, Hillcoat & A.G. Miller	p/sl	R			2	1		1	1		Medium green spiky stems. Flowering clumps attract many flying insects. Rare in WWNP generally, but occasional in upper W. Ghulayyil Khun (WWNP buffer zone). Found elsewhere in diverse environments (slopes, plateaux, sand flats). Locally common in Hajar Mtns and Ru'us al-Jibal.
Resedaceae	***Ochradenus***	***aucheri***	Boiss.	p/sl	L		2	1	1		1	2		Stems whip-like and normally leafless but post-rain growth may feature linear leaves. Common in W. Ghayl but less so in other tributaries of W. Wurayah.
Resedaceae	***Oligomeris***	***linifolia***	(Vahl) J.F. Macbr	a/e	R		1		1					Small, ruderal species. Common in peri-anthropic waste ground.
Resedaceae	***Reseda***	***aucheri***	Boiss.	a/e	L		1	2	1					Species identification is based on Ghazanfar (2003). Three similar species have been recorded from the Hajar Mtns: *R. arabica*, *R. aucheri* and *R. muricata* (Ghazanfar 2003, Jongbloed 2003). Descriptions differ somewhat among those authorities and Boulos (1999) but only *R. aucheri*, described in Ghazanfar (2003), has smooth, shiny seeds, as found in WWNP specimens collected by the author. Ghazanfar (2003) also gives "its usually entire leaves" as a secondary distinguishing characteristic of *R. aucheri*, consistent with WWNP specimens. On this basis, all Reseda seen in WWNP were recorded as *R. aucheri*.

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Rhamnaceae	***Ziziphus***	***spina-christi***	(L.) Willd.	p/t	C		1	2	2		1			Largest tree species of the Hajar Mtns in the UAE. [NB: A few straggling specimens in wadi beds, with dense, tomentose growth form, were examined to investigate the possible presence of *Z. lotus*, recorded in UAE between Masafi and Fujairah by Karim & Fawzi (2007), but no determination could be made in the absence of flowers and seeds. Morphology appeared consistent with adaptation of *Z. spina-christi* to situs in a wadi bed prone to flooding, but possibly *Z. lotus* has been overlooked.]
Rubiaceae	***Callipeltis***	***cucullaris***	(L.) Steven	a/e	R		1	1						Small annual, resembling some caryophylls. Single specimen recorded in wadi bed in upper W. Siji (WWNP buffer zone).
Rubiaceae	***Galium***	***decaisnei***	Boiss.	a/e	O		2	1			1	1	1	Syn. *G. setaceum*. One of the most delicate higher plants in the Hajar Mtns. Favors sheltered locations.
Rubiaceae	***cf. Galium***	***sp. 1***		a/e	E		1							Provisional photo ID of historical record from W. Zikt (by Feulner, 01/2012). The tiny plant resembles a seedling of three very similar *Galium* spp. that have all been professionally ID'd from Ru'us al-Jibal: *G. aparine*, *G. ceratopodum* and *G. tricornutum*.
Rubiaceae	***Plocama***	***aucheri***	(Guill.) M. Backlund & Thulin	p/sd-sl	C		1	1	1		1	1		Syn. *Gaillonia aucheri*. One of the most common larger shrubs. White, rectilinear, spiky stems with medium to dark green worm-like leaves. Skeleton-like when dry; woolly-looking when in flower. Not browsed.
Rubiaceae	***Plocama***	***hymenostephana***	(Jaub. & Spach) M. Backlund & Thulin	p/sd	O		2	1	2		1			Syn. *Pseudogaillonia hymenostephana*. Leaves opposite, elongate, dark green, with prominent centreline and slightly fuzzy. Seed wings are unmistakeable 'pink buttons'.
Rutaceae	***Haplophyllum***	***tuberculatum***	(Forssk.) A. Juss.	p/sd	C		2	1	1		1	2		Exceptionally aromatic. Leaves highly variable in shape but always tubercular on underside. More common in wet years. Markedly refreshed in June by rain in late April. Foodplant for Common Swallowtail butterfly *Papilio machaon*.
Sapindaceae	***Dodonaea***	***viscosa***	Jacq.	p/sl	O		1				1			ID'd by erect form and elongated lanceolate leaves. Not browsed. Most shrubs in WWNP are relatively small and are found along the banks of tributary wadis and gulleys.
Scrophulariaceae	***Anticharis***	***glandulosa***	Asch.	a/e	R		1	2						Widespread but rare, usually in wadi beds. Glandular, sticky, cupped leaves.
Scrophulariaceae	***Chaenorrhinum***	***rubrifolium***	(DC.) Fourn. subsp. *gerense* (Stapf) D.A. Sutton	a/e	R		1							Few plants in upper W. Siji (WWNP buffer zone). In the UAE, this species is localised in the Masafi area but also recorded from single locality in western Ru'us al-Jibal, above W. Sha'am.

						H	A	B	I	T	A	T	S	
Family	Genus	Species	Authority for Nomenclature	Growth & Form (refer to key at end)	Abund. (WWNP) (refer to key at end)	Pools	Wadi	Wadi Slope	Terrace	Terrace (Silt)	Gulley	Slope (Stony)	Slope (Rocky)	Remarks
Scrophulariaceae	***Lindenbergia***	***arabica***	(Moore) Hartl.	p/sd	R		1	2						Endemic to Hajar Mtns of UAE & N.Oman. Typical situs is on gravel wadi wall. Few plants seen at scattered locations in lower Waterfall Wadi, lower tributary of W. Ghayl, and upper W. Siji. Single historical record from W. Zikt (by Feulner, 01/2012). More common on west flank of Hajar Mtns, especially in Wilayat Mahdhah of Oman, where it is occasional.
Scrophulariaceae	***Lindenbergia***	***indica***	(L.) Vatke	p/sd	R		1							Single historical record (by Feulner, 01/2012) of two plants from tributary of mid-W. Zikt (WWNP buffer zone). Typical situs is at base of gravel wadi wall.
Scrophulariaceae	***Misopates***	***orontium***	(L.) Rafin.	a/e	O		1	1						First recorded in late January 2013, more than 4 weeks after heavy rain. Occasional, widespread but scattered, in March 2013. Common at HQ area in Jan 2014, in fine gravel of rolling terraces and wadi.
Scrophulariaceae	***Nanorrhinum***	***elatinum***	(L.) Dumort.	a/s	R		1							Two specimens in damp wadi gravel among rocks, upper W. Zikt, Jan 2014. Also historical record from upper W. Abadilah (by Feulner, 10/2003), next to pool with *Typha domingensis*. Originally ID'd by the author as *N. acerbianum* (syn. *Kickxia acerbiana*) but probably identical with *N. elatinum*, subsequently collected and determined from W. Wurayah by Shahid & Rao (2015) (as *K. elatine*). The latter determination is supported by reference to Boulos (2002).
Scrophulariaceae	***Nanorrhinum***	***hastatum***	(R. Br. ex Benth.) Ghebr.	a/e	O		1	1	1		1			Syn. *Kickxia hastata*. Scattered small, erect plants among rocks of gravel wadis, slopes and terraces. May be much larger and straggling where sheltered. In flower March-June. *N. ramosissimum*, a very similar SW Asian species recorded in the literature from UAE mountain areas generally, but rare, was not distinguished in WWNP. Possible synonymy of *N. hastatum* and *N. ramosissimum* should be reviewed.
Scrophulariaceae	***Schweinfurthia***	***imbricata***	A. Miller	a/p	R		2							Endemic to Hajar Mtns of UAE & northernmost Oman. Two specimens from WWNP – one in silt behind Wurayah Dam (02/2013) and one along the distal surface water outflow below Wadi Wurayah waterfall (11/2014) – are the northernmost UAE records and the only ones from the East Coast. The nature of these records, along with another from the brick and concrete walkway of the Siji Dam, confirm the opportunistic and ruderal character of this species.
Scrophulariaceae	***Schweinfurthia***	***papilionacea***	(Burm. f.) Boiss.	a/e	R		1	1						Few plants at two locations in upper W. Siji (WWNP buffer zone).

						H	A	B	I	T	A	T	S	
Family	**Genus**	**Species**	**Authority for Nomenclature**	**Growth & Form (refer to key at end)**	**Abund. (WWNP) (refer to key at end)**	**Pools**	**Wadi**	**Wadi Slope**	**Terrace**	**Terrace (Silt)**	**Gulley**	**Slope (Stony)**	**Slope (Rocky)**	**Remarks**
Scrophulariaceae	***Scrophularia***	***deserti***	Delile	p/sd	O		1	1						Dark green, lobate, dull glossy basal leaves and erect, "jester's hat" inflorescence are distinctive.
Solanaceae	***Hyoscyamus***	***muticus***	L.	p/s	R		1	2						Historical record (by Feulner, 10/2003) from gravel wadi bed in upper Wadi Abadilah (WWNP buffer zone).
Solanaceae	***Lycium***	***shawii***	Roem. & Schult.	p/sl	E			1						Single historical record, W. Yashimah (by Feulner, 10/2003). Tall, scraggly specimen growing in *Ficus johannis*.
Solanaceae	***Physalis***	***minima***	L.	a/e	R		1							Few plants in wadi gravel at picnic area along effluent stream at base of waterfall.
Solanaceae	***Solanum***	***lycopersicum***	L.	p/sd	E			2						Cultivated tomato. Historical record of two small plants in wadi gravel at roadhead (by Feulner, 05/2008).
Tiliaceae	***Corchorus***	***depressus***	(L.) Stocks	p/p	R					1				Single site. Few plants in silty depression on partly bulldozed terrace above lower W. Ghayl. Rare in mountains, but Jongbloed (2003) says it is "Locally common along the plains . . . of the East Coast."
Tiliaceae	***Grewia***	***erythraea***	Schweinf.	p/sl	R			2	1		1	1	2	Grows to small tree size if not browsed, but often grazed to cushion. Specimens tend to be clustered, e.g., several in Nimriyah area of Wadi Zikt, several at base of sidr trees at Aqabat al-Kharus, and several on terraces in Dam Wadi.
Urticaceae	***Forsskaolea***	***tenacissima***	L.	a/e	C		1	1	2		1	2	2	"Velcro" plant. Can be hyperabundant at sheltered sites with gravel or stony substrate.
Urticaceae	***Parietaria***	***alsinifolia***	Delile	a/s	C		1	1			1			Favours sheltered sites, but can also be found in open gravel in upper wadis.
Violaceae	***Viola***	***cinerea***	Boiss.	a/e	O		2					1		Small, delicate. Basal rosette of shiny, spade-shaped leaves. Opportunistic and found at all elevations, but favours silt within gravel or rocky sites.
Zygophyllaceae	***Fagonia***	***brugueri***	DC.	p/p	C		2	1	1	1		1		Prostrate or straggling, and spiny (sometimes densely so). Preferred habitat is open gravel plain or gentle slope. [NB: Small, dense plants appear to be browsed seedlings of more diffuse ones, but it is possible that these may constitute two separate species. This should be investigated.]
Zygophyllaceae	***Fagonia***	***indica***	Burm. f.	p/sd	R							1		Two locations only, both in WWNP buffer zone: (1) single scrawny plant in scree gulley in upper Nimriyah area of W. Zikt, below pass to W. Ghayl; (2) one large plant and one probable smaller plant in upper W. Siji, in wadi gravel under a shaded recess in terrace wall.
Zygophyllaceae	***Tribulus***	***terrestris***	L.	a/p	L		2		1					Small prostrate on gravel terraces, ID,d by seeds.

KEY TO CHECKLIST

Growth & Form:
a/e = annual, erect
a/f = annual, fern
a/g = annual, grass
a/p = annual, prostrate
a/s = annual, spreading
p/f = perennial, fern
p/g = perennial, grass
p/h = perennial, herb
p/p = perennial, prostrate or straggling
p/sd = perennial, dwarf shrub
p/sl = perennial, large shrub
p/t = perennial, tree

Abundance (For definitions, see accompanying report, The Flora of Wadi Wurayah National Park, Fujairah, United Arab Emirates, at section 1.1.5)**:**

H = Hyperabundant (in optimal cond'ns)
C = Common
L = Locally Common
O = Occasional
R = Rare
E = Exceptional

Habitat:
1 = primary habitat
2 = secondary habitat

"Historical records" refer to all records prior to the commencement of the baseline survey in December 2012.

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A Geological Excursion to Jebels Rawdah, Buhays and Faiyah

by Graham Evans and Anthony Kirkham

Fig. 1. General Location map

This one-day excursion involves off-road driving and a moderate amount of clambering over rough terrain. It concentrates mainly on the Maastrichtian (latest Cretaceous) Qahlah and Simsima Formations and the overlying Palaeocene Muthaymimah Formation at Jebels Rawdah, Buhays and Faiyah (Figs. 1 and 2). The Simsima Formation provides the main oil reservoir of the Shah Field which is located in the Liwa region of the UAE.

Whilst Jebels Buhays and Faiyah are located within the UAE, Jebel Rawdah is located in Oman and it is necessary for individuals to display their passports (not copies of) at the Omani border post along the road to Hatta from Al Madam although no visa is required. Four-wheel drive vehicles are recommended for such an excursion.

All three jebels are eroded remnants of anticlinal structures but Jebel Rawdah also includes a syncline. The folding occurred during the Oligo-Miocene.

Jebel Rawdah

This jebel is located on the northern side of the highway from Al Madam to Hatta, 15 kms east of Al Madam. Structurally, the jebel represents an eroded anticline-syncline couplet with a WNW-ESE trend. Viewed from the highway, light brown Simsima Formation overlies palaeo-hills mainly composed of black Semail ophiolite (former oceanic crust / upper mantle) and Hawasina Group sediments which were tectonically emplaced by obduction during the Campanian (Late Cretaceous).

Conglomeratic Qahlah Formation only locally separates the allochthonous strata from the orange-yellow coloured Simsima Formation as it mainly infills palaeovalleys but this formation is not easily accessible during this excursion. It will be examined at Jebel Buhays. Creamy white coloured Palaeocene Muthaymimah Formation overlies the Simsima Formation which appears to wedge out eastwards. The top of the Simsima Formation is reddened possibly due to exposure prior to Muthaymimah deposition or to lateritic outwash from contemporaneously exposed lateritic palaeosols at top ophiolite (Fig. 3a). In the extreme east, the Muthaymimah Formation directly overlies ophiolite but appears to progressively onlap the Simsima Fms. westwards although faulted contacts may also occur (Fig.3b).

From the Hatta road, the jebel is best approached by driving north along dirt tracks across the core of the eroded anticline towards the lowest point of the ridge (Fig. 4) defining the northern limb of the anticline / southern limb of the syncline. Here one can ascend to the crest of the ridge by crawling upwards along an extensive dipping fracture plane within the Simsima Formation. The shallow marine limestones of the Simsima Formation are dominated by diagenetic calcite nodules which are also extremely common in the Shah Field reservoir. The intensity of these nodules varies throughout the formation and they often impinge on each other to the exclusion of original sedimentary texture. Near the base of the ridge, slightly to the west of the lowest point, one can observe *in situ* rudist fossils (extinct bivalves; Fig. 5a).

Fig. 2 a) general location map, b) Jebel Rawdah, c) Jebel Buhays, d) Jebel Faiyah. Images extracted from GoogleEarth.

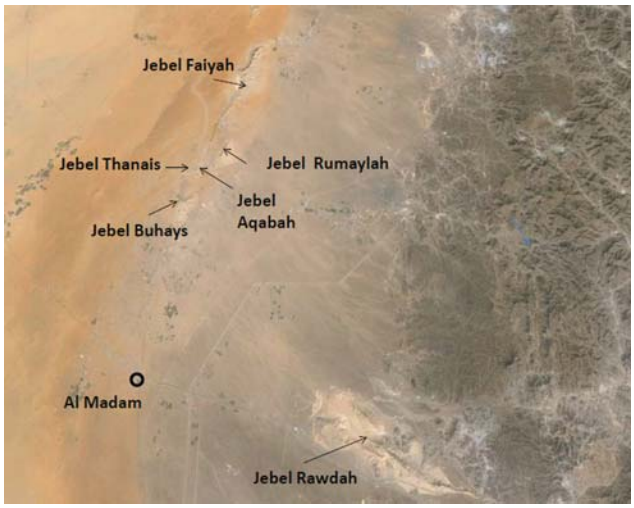


Fig. 2: a

Fig. 2: b

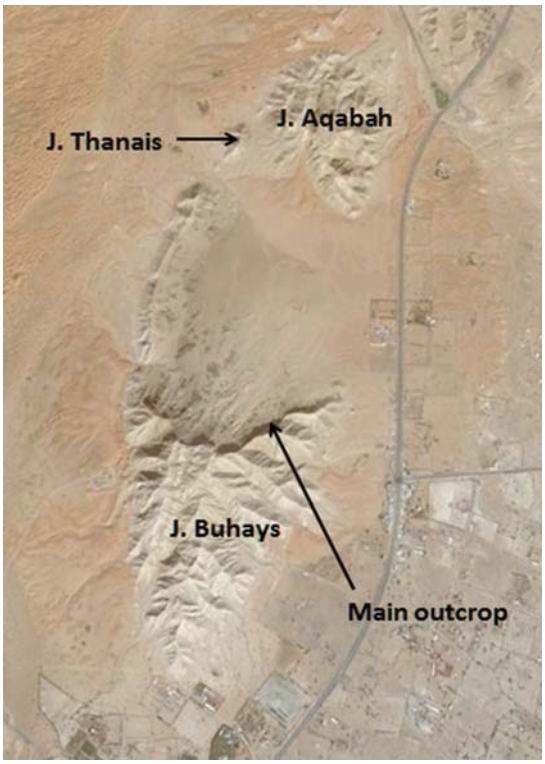


Fig. 2: c

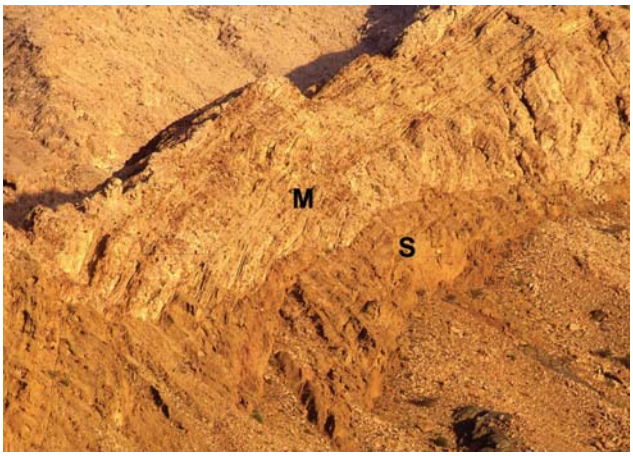
Fig. 2: d

The Simsima Formation was exposed and karstified prior to Muthaymimah being deposited with strong angular unconformity. Karst breccias fill fissures in the Simsima Formation. From the ridge crest one gains an impressive panoramic view of the Muthaymimah Formation outcropping in the core of the syncline north of the ridge.

Traversing the northern side of the ridge crest for about 100 metres, one can examine the unconformable contact. The lowermost Muthaymimah Formation is massively bedded and includes large angular exotic clasts of both carbonates and reddish 'basement' lithologies which were emplaced as submarine debris flowed along a submarine slope channel (Fig. 6a-c and 7). They are interbedded with, and pass up into, thin bedded muddy limestones containing marine planktonic foraminiferids indicating their accumulation as deep water oozes. They also contain dark brown chert nodules probably formed from remobilised silica of sponge spicules which are known to have occurred within the formation. Some of these thinner Muthaymimah beds, especially in the core of the syncline, display Bouma sequences indicative of calciturbidites. The deep water origin of the Muthaymimah Formation contrasts markedly with the relatively shallow water Simsima Formation. The sharp change in depositional setting was possibly due to contemporaneous faulting associated with rifting around the Cretaceous-Tertiary boundary. The slight change in dip and strike across the Simsima-

Fig. 3 Jebel Rawdah. a) Note the grey 'basement' lithologies to the right forming a palaeotopography infilled and overlapped by red topped Simsima Formation (S) which is onlapped or in fault contact with Muthaymimah Formation (M). Simsima Fm has pinched out to the right of the picture. The foreslope comprised slumped Simsima Formation b) Simsima Formation is onlapped or in fault contact with lighter coloured Muthaymimah Formation to the east of the excursion location.

a



b

Fig. 4 Excursion location at the lowest point of the ridge looking north. Note the fracture plane (arrowed) up providing an easy route to the ridge crest.

Fig. 5 Example Simsima Formation fossils. a) a bouquet of the rudist, *Durania,* Jebel Rawdah b) specimens of the rudist, *Dictyoptychus,*.Jebel Faiyah c) *Dictyoptychus in* a matrix rich in orbitoidal foraminiferids, Jebel Faiyah. d) a large gastropod, *Campanile*, Jebel Faiyah.

a

b

c

d

Muthaymimah boundary is evidence of tectonic disturbance at the end of the Cretaceous.

One can either retreat to the base of the ridge by retracing steps along the route already taken or one can clamber relatively easily down a gully at the deepest part of the erosional channel (about 50 metres west of the ascent route). Some of these gullies expose the karstic breccias.

The northern limb of the syncline is accessible by vehicles along a dirt track around the western side of the jebel and has been a fruitful site for the collection of echinoid specimens by palaeontologists of the Natural History Museum, London.

Jebel Buhays

This represents the southern plunge of an eroded north-south trending anticline located on the western side of the highway from Al Madam to Dhaid, 12 kms north of Al Madam. Jebels Thanais and Aqabah constitute remnants of the northern plunge. Excellent rock outcrops can be approached by vehicle along a dirt track which passes a very tall radio mast on the northern flank of Jebel Buhays. The Simsima Formation is conspicuous with its heavy superficial coating of 'dripstone' caliche but about one kilometre from the main road is a prominent vertical wall of 'clean' exposure displaying good sedimentary layering worthy of close inspection (Fig. 8a).

A relatively easy climb to the base of this Simsima exposure begins with a traverse across dark serpentinised ophiolite. The ophiolite is overlain by a conglomeratic interval assigned to the Maastrichtian Qahlah Formation which comprises well rounded ophiolite pebbles and is interpreted as a beach deposit although with fluviatile basal sediments (Fig. 8b). The Qahlah Formation is overlain abruptly by the bedded Simsima Formation which again reveals abundant calcareous concretions. However, here it is obviously far more fossiliferous and displaying, for instance, abundant benthonic orbitoidal foraminiferids, red algal rhodoliths, large rudists (*Dictyoptychus* and *Durania*) and large gastropods (*Campanile and Acteonella*) (Figs. 8c, d and 9).

Half a kilometre further west along the dirt track is exposed a far greater thickness of the Qahlah Formation overlying the ophiolites.

The Muthaymimah Formation is well exposed in all the valleys around the southern side of Jebel Buhays. It is dominated by mass gravity flow deposits (Fig. 10) including calciturbidites and olistostromes (mega debris flows) containing olistoliths (clasts) as large as automobiles.

Fig. 6 Muthaymimah Formation, Jebel Rawdah. : a) – c) exotic clasts within channelised debris flows at the base of the formation. d) thin bedded, laminated carbonate oozes with chert nodules (arrowed). Car key for scale.

a

b

c

d

Jebel Faiyah

This jebel is a ridge located immediately north of the Jebel Buhays anticline again on the western side of the Al Madam - Dhaid highway, 17 kms north of Al Madam. It forms the western limb of a north-south trending anticline. Jebel Rumaylah on the opposite, eastern side of the highway is the eastern limb of the same anticline. Unfortunately, a metal fence has been erected around much of Jebel Faiyah and therefore limits access. The most rewarding approach is via a municipal rubbish tip in front of the lowest point of the north-south ridge. Permission should be sought from the on-site officials in charge of the tip before driving to the foot of the ridge. A steep dirt track passes over the ridge but it is not advisable to drive along it. Walking is recommended. Alternative access may be possible by driving around the southern tip of the jebel and along the western side.

Again the patchy Qahlah and/or shallow marine Simsima Formation overlie ophiolites and the Simsima Formation is again extremely fossiliferous. The Muthaymimah Formation again comprises calciturbidites and olistostromes. Although the Muthaymimah Formation has an unconformable base throughout the region, there is actually a tectonic contact between the Simsima and Muthaymimah Formations at this locality (Fig. 11). A steep walk up the ridge at its lowest point behind the municipal tip provides a stunning view of a thrust plane between these two formations. Calciturbidites of the Muthaymimah Formation reveal drag curvature immediately above the thrust plane, thus indicating easterly thrusting.

Footnote: Noweir *et al*. (1998) identified Maastrichtian foraminiferids within the Muthaymimah Formation and so renamed the the Muthaymimah as the Upper Simsima Member. They stated that the 'Muthaymimah' Formation was conformable on the Simsima Formation in the Faiyah Range area whereas Nolan *et al*. (1998) and Skelton *et al*. (1998) described at least a low angle unconformity to strong erosional contact. It is likely that Maastrichtian foraminiferids were reworked into Palaeocene resedimented carbonates that now comprise the Muthaymimah Formation. Nolan *et al*. (1998) described such reworking .

Abou Sayed and Mersal (1998) adopted the reassignment of 'Muthaymimah' as Upper Simsima at Jebel Rawdah without discussion but there is extremely strong lithostratigraphic evidence to separate out the Simsima and Muthamimah Formations at that locality.

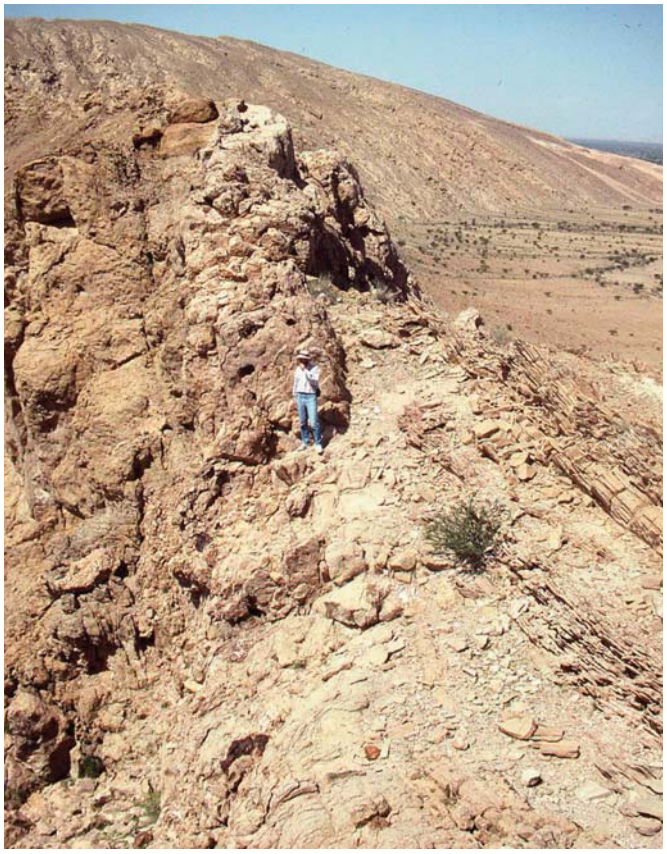


Fig. 7 Looking west along the crest of the ridge at Excursion locality, Jebel Rawdah. Arrows indicate the erosional contact between the Simsima (left) and Muthaymimah (right) Formations. The basal Muthaymimah Formation comprises mainly debris flow carbonates with angular exotic clasts interbedded with flaggy carbonate oozes. Note the difference in strike between the two formations.

Fig. 8 Excursion locality, Jebel Buhays. a) Simsima Formation with dripstone caliche covering upper surface. Note the geologist for scale. The Simsima overlies Qahlah Formation with sharp contact. b) Qahlah Fm comprising monomict conglomerate with well rounded pebbles and cobbles. c) and d) Close-up of a) showing variations of concretions, molluscs and rhodoliths. Large protrusive elements of d) are *Dictyopticus* rudists.

a

b

c

d

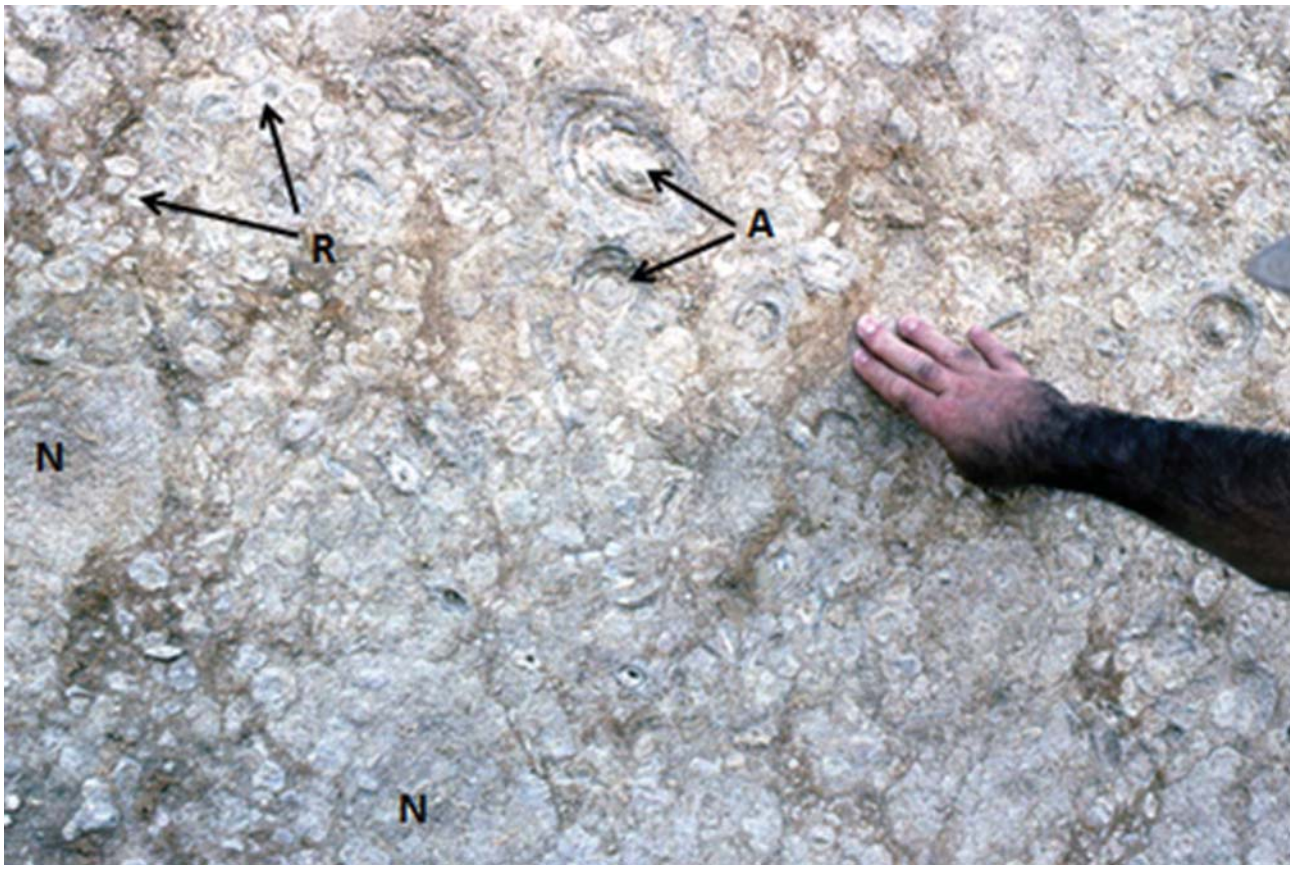


Fig. 9 Close-up of Excursion locality, Jebel Buhays, showing large gastropods, *Acteonella*, (A) surrounded by red algal rhodoliths (R) and large nodules (N).

Fig. 10 Muthaymimah Formation comprising deep water carbonates, some of which comprise olistostromes, Jebel Buhays.

Fig. 11 Thrust contact between buff coloured shallow marine Simsima Formation and lighter coloured, deeper water Muthaymimah Formation. Thrust movement was from left to right and caused drag of the Muthaymimah Formation which comprised calciturbidites and olistostomes. Arrows indicate olistoliths. Note the geologist for scale.

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New Evidence of the Quaternary History of Abu Dhabi: A Pleistocene Evaporite Deposit near Yas Island

by Graham Evans and Anthony Kirkham

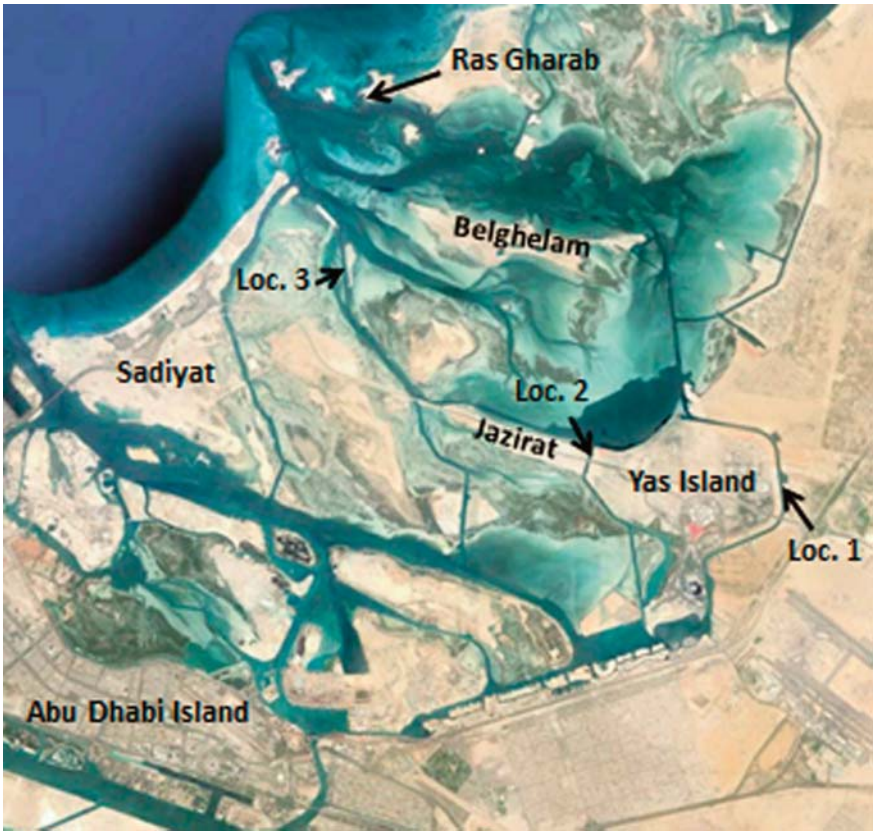

Fig. 1 General location map (based on a satellite image from Google Earth). Note the canals that partly define Yas island. Note also the localities mentioned in this report.

Yas Island is a feature which has been created artificially by the cutting of canals across the NW-SE trending Jazirat (Habel al-Abyadh) peninsula. Today it is the site of a Formula 1 racetrack and across it runs the relatively new Sadiyat Road from Abu Dhabi to Dubai (*Fig. 1*). The topography of the peninsula is dominated by weakly cemented, wind blown, calcareous dune sand (aeolianite; sometimes called 'miliolite') of the Pleistocene Ghayathi Formation. It displays abundant, well developed, large scale, cross-stratification and is the remains of a deflated Pleistocene seif dune created in response to the palaeo-Shamal winds (Kirkham, 1998a). Numerous such fossil dunes extend across the Emirates and form the cores of the coastal barrier islands.

At Locality 1 (*Fig.1*; GR24°29'35"N, 54°38'04"E), the cross-bedded aeolianite is separated locally from an underlying, flat topped, coarsely bioclastic marine limestone by a 40 cm thick, reddish gypsum layer (Evans and Kirkham, 2005; Kirkham, 2011; *Fig. 2*). Curiously, the excellent exposures of gypsum in the banks of the canal were not mentioned by Ferrant *et al.* (2012). In fact, their maps suggest that the aeolianite overlies Miocene strata rather than Pleistocene marine limestone. Evans *et al.* (1969) recorded Miocene dolomite beneath the Quaternary at Musaffah and Peebles *et al.* (1994) described Miocene dolomite and evaporites in six boreholes along the Musaffah Channel. Examination of the microfossil assemblage was unable to define the age of the limestone beneath the massive gypsum bed on Jazirat but the general appearance and non-dolomitic mineralogy persuades the present authors that this sub-gypsum layer is Pleistocene.

How far the gypsum layer extends along the Jazirat is impossible to tell. At Locality 2 (*Fig. 1*; GR24°30'15"N, 54°34'22"E) a second canal cutting reveals that the base of the aeolianite dips below average mean sea level and thus the gypsum layer would therefore be obscured even if present. At Locality 1 the gypsum is massive and pinches out north and south towards the flanks of the palaeo-seif at least partly due to aeolian deflation (*Fig. 3*). Where the gypsum bed is absent beyond the pinchouts, the aeolianite rests directly upon the Pleistocene marine limestone which is capped by a possible hardground or a fossil beach rock with ripples.

Fig. 2 The massive, gypsiferous layer sandwiched between underlying, relatively flat-topped, horizontally bedded Pleistocene marine limestone and overlying Pleistocene aeolianite. The lineations on the marine limestone are scrape marks created by digging equipment used to excavate the canal but the aeolianite displays true cross-stratification dipping to the right. Gypsum bed is about 40 centimetres thick. Locality 1, looking east.

Thin section analysis reveals that the gypsum layer contains irregular patches of carbonate sediment. The gypsum crystals are often poikilitic but with an occasional lozenge-shaped crystalline habit and there are anhydrite relicts within some gypsum crystals. The absence of nodules and banding, combined with its sharp upper and lower bed boundaries tend to argue against a coastal sabkha origin for this gypsum bed and it was most likely deposited as a salina across which the palaeo-seif later migrated. It is probable that the salina originated from sea water impounded behind a coastal barrier. Other Pleistocene gypsiferous deposits were recorded by Williams (1999) in various offshore wells such as at Umm Shaif oilfield and the Zakum oilfield, which he, in contrast, interpreted as peritidal / sabkha in origin.

It is particularly significant that Locality 1 is the only site known to the present authors where a Pleistocene evaporite, in contrast to the Holocene sabkha evaporites, is exposed in the UAE. Elsewhere, the base of the Pleistocene aeolianite is exposed on Marawah Island and succeeds a beach deposit which in turn overlies a reefal limestone dated as 160-280,000 yrs old (Evans *et al*., 2002; *Fig. 4*). A temporary excavation on the Abu Dhabi-Jebel Dhanna road near the turning to Al Aryam Island revealed >6 m of Pleistocene brown siliciclastic aeolian sand which is known to underlie the entire Holocene coastal sabkha plain (Evans & Kirkham, 2009a). Shallow pits dug at other localities in the vicinity of Tarif show that the aeolianite overlies this same siliciclastic aeolian deposit (*Fig. 4*). A similar stratigraphic relationship was once originally exposed in the Musaffah Channel (Kirkham, 1998b). Elsewhere, the base of the aeolianite is sometimes exposed directly overlying Miocene siliciclastic strata inland of the coastal sabkha.

It appears that during the low sea-levels of the penultimate glacial period, a sheet of aeolian carbonate dune sand, derived from the exposed shelf carbonate sediments, extended landwards over a diverse landscape to cover beach sands on Marawah Island and extended landwards to cover both the deflated desert siliciclastic sands which underlie the coastal sabkha plains and Miocene strata further inland. Elsewhere, such as at Locality 1, the advancing aeolianite covered peritidal carbonates and the gypsum deposits of hypersaline shallow-water ponds or hypersaline fringes of the inner parts of lagoons.

The subsequent Pleistocene sea-level rise resulted in the deposition of a shallow marine limestone (Fuwayrit Formation) above the aeolianite over large parts of the present day coastal areas as revealed by scattered deflationary zeugen composed dominantly of aeolianite capped by a shallow water marine limestone dated as approximately 125,000 yrs BP, *ie.* last interglacial (Stevens *et al*, 2011; Stevens *et al*, 2014). This marine transgression created Pleistocene cliff scree deposits around the palaeo-seifs near the northernmost regions of the barrier islands to the west of Abu Dhabi Island such as Al Dabb'iya (Kirkham, 1998a; Evans and Kirkham, 2005) and Al Aryam

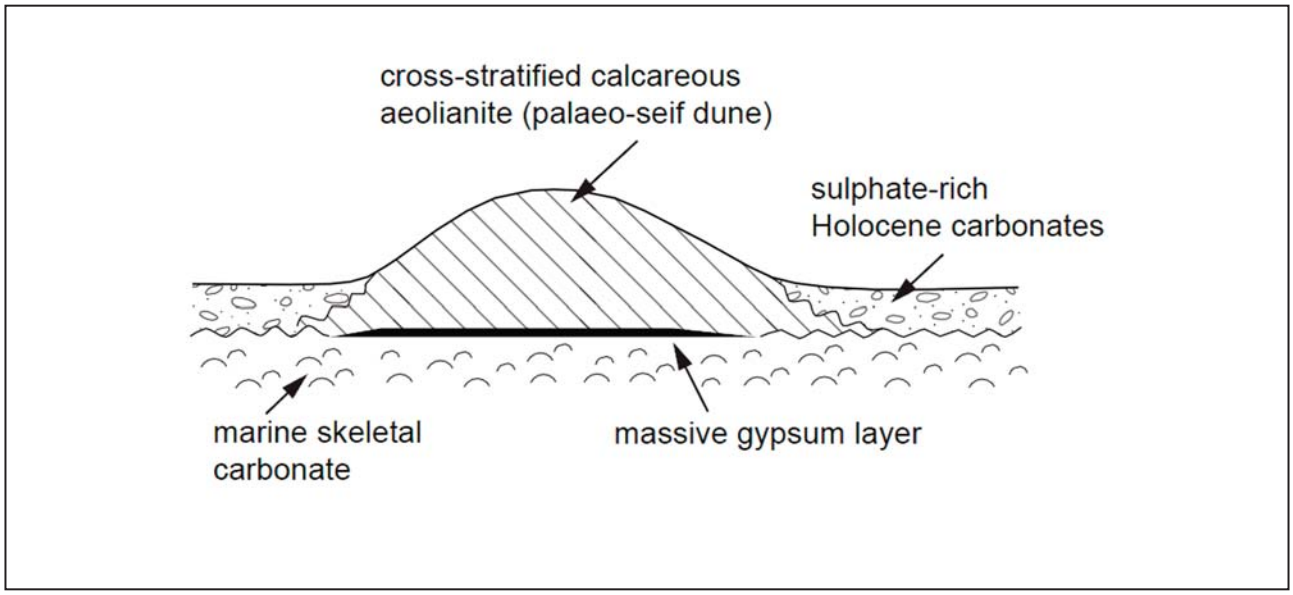

Fig. 3 Schematic reconstruction of the bank of canal across Jazirat (Habel al-Abyadh) showing Pleistocene deposits and onlapping Holocene gypsiferous carbonates.

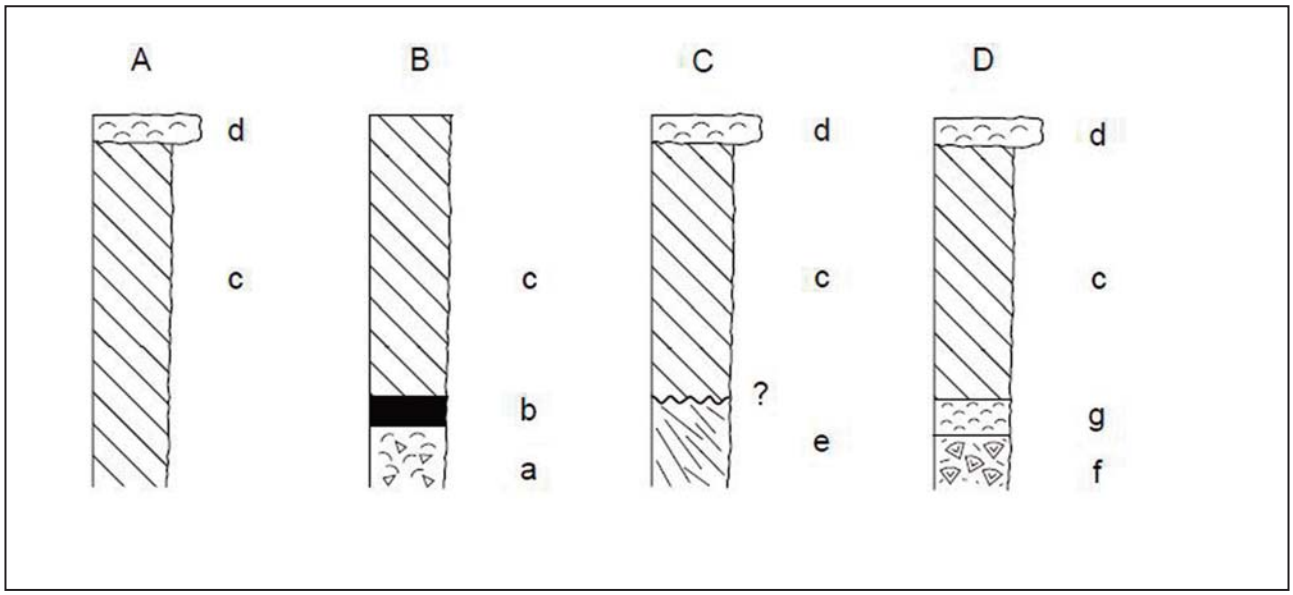

Fig. 4 Simplified logs showing the relationship of the Pleistocene Ghayathi Formation and the overlying Pleistocene Fuwayrit Formation (approximately 125,000 BP in age). A = Ra's Gharab, B = Yas Island Locality 1, C = West of Tarif, D = Marawah Island. a = marine skeletal carbonate, b = massive gypsum, c = cross-stratified calcareous aeolianite, d = marine skeletal carbonate often with caliche, e = brown cross-stratified siliciclastic aeolian sand, f = coral rich skeletal carbonate, g = marine skeletal carbonate with birds-eye structure. Heights of the various vertical sections vary between 3 and 5 metres.

(Evans and Kirkham, 2009a). However, at Location 1, the palaeo-seif dune shows no evidence of this Pleistocene marine sediment as the capping rock has perhaps been removed by erosion or the dune was too far inland for it to be onlapped or inundated by the marine transgression. These marine sediments are also absent from Belghelam where the Pleistocene aeolianite is even greater in height (Evans and Kirkham, 2009b). However, they were present further north at Ra's Gharab and Locality 3 (Fig. 1; Stevens *et al*, 2014). This interpretation contrasts markedly to that proposed by Wood *et al.* (2012) and seemingly supported by Ferrant *et al.* (2012).

The flanks of the palaeo-seif are onlapped by evaporitic Holocene carbonates (Kenig, 1991, 2012) which lie directly upon the underlying Pleistocene marine carbonates (*Fig. 3*). These have a muddy texture and are quite rich in individual gypsum crystals several centimetres in diameter and which typically form slowly beneath the water table under coastal sabkha conditions. Supratidal anhydrite also occurs in these Holocene carbonates in close proximity to Locality 1.

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The exuviae of the Urothemistinae of the Arabian Peninsula including the first description of the exuvia and final instar larva of *Urothemis thomasi* Longfield 1932 (Odonata: Libellulidae)

by David Chelmick (DGC), Richard Seidenbusch (RS), Jean-Pierre Boudot (JPB) and Christophe Brochard (CB)

Key words: Odonata, dragonfly, larval description, Urothemistinae, *Urothemis thomasi*

Abstract

The exuviae of all four species of Urothemistinae known from the Arabian Peninsula (*Macrodiplax cora*, *Selysiothemis nigra*, *Urothemis edwardsii* and *U. thomasi*) were collected on recent surveys in UAE and Oman. The exuvia of *Urothemis thomasi*, first discovered in 2013, is described here for the first time. This paper, when used in conjunction with Suhling *et al.* (2014), provides sufficient information for all species of Libellulidae currently known from Arabia to be identified from final instar larvae and/or exuviae. It is hoped that this will encourage local naturalists to collect and identify specimens, which will improve knowledge of this region of which large areas remain little known.

Introduction and Discovery

On 7 June 2013 *Urothemis thomasi* was recorded for the first time in the United Arab Emirates (UAE), from Wadi Wurayah National Park (WWNP) (Feulner & Judas 2013). Present on that occasion as a visiting naturalist was one of the authors, DGC, who during his visit collected exuviae from WWNP. In the autumn of 2013, DGC examined the collected material and found a large libellulid exuvia that he was unable to identify. Photographs were circulated to a number of authorities with no success. Eventually, CB took more and better photographs and then sent the material on to RS, who examined it in detail. RS listed the following features as being those unique to the genus *Urothemis* within the Urothemistinae, which is one of the few subfamilies still recognised in the Libellulidae, along with the Libellulinae and the Leucorrhiniinae (Ware *et al.* 2007; Dijkstra *et al.*, 2013):

- eyes strongly directed and elongated backwards;
- well expressed body setulation;
- long, slender and tapering antennal segment 7;
- triangular shaped poststernum which is present in very few genera of Libellulidae and illustrated in Figure 3 below;
- wide and flat-notched distal frons (wider than submental width);
- crenulated distal border of palp;
- softly curved connection between arch and lobe; and
- short epiproct and short anal pyramid.

Having concluded that the specimen was a member of the genus *Urothemis* and knowing that *U. thomasi* had recently been recorded from the same site, RS proposed that the exuviae was that of *U. thomasi*, which is the only species of this genus known from the UAE.

In a subsequent trip to Wadi Wurayah in April 2014, DGC collected a late instar larva and an additional exuvia of this species. This material was augmented on a trip to Oman in Autumn 2014, where Christian Monnerat , a Swiss researcher, collected larvae. These specimens were passed to CB for photographing and breeding out. Unfortunately, all these specimens died immediately prior to emergence.

In October 2014 and thanks to funding from the Mohamed bin Zayed Species Conservation Fund, a field trip into the UAE and Northern Oman took place with the prime purpose of establishing the status and distribution of *U. thomasi* in the region. This trip again found adults and exuviae of *U. thomasi* in Wadi Wurayah in the UAE, but not yet in Northern Oman. A second field trip took place in April 2015, which included the Dhofar province of southern Oman,and was successful in finding exuviae of *U. thomasi*, together with exuviae of three other species pertaining to the regional Urothemistinae. Most importantly, Anthony Stoquert, a member of the second field trip, collected a live larva of *U. thomasi* from Dhofar This latter was first reared in the field station at WWNP by Patricia Cabrera, then by Philippe Lambret who took it to the Tour du Valat research station (Camargue, France) and various other locations during further displacements up to its emergence in August 2015. The emergence confirms the original RS identification.

DGC was not present during the second trip but was charged with the identification of the collected exuviae material. The Urothemistinae exuviae examined for purposes of this paper are set out below and were collected by DGC from UAE and Oman and by Anthony Stoquert during the first and second field trips to Oman, respectively:

- *Macrodiplax cora* – 4 ex.
- *Selysiothemis nigra* – 9 ex.
- *Urothemis edwardsii* – 9 ex.
- *Urothemis thomasi* – 8 ex.

RS has provided additional expertise and was able to correct some of the original assumptions made by DGC. This paper summarises the identification of all the Urothemistinae found in the Arabian Peninsula and provides a detailed description of the exuvia /final instar larva of *U. thomasi* for the first time. Details of the biology and ecology of *U. thomasi* have not been included here but are to be found in Lambret *et al.* (2015).

The Urothemistinae of Arabia

The Arabian Peninsula, hereinafter referred to as Arabia, consists of the Kingdom of Saudi Arabia, Kuwait, the Republic of Yemen, the Sultanate of Oman, the United Arab Emirates, Qatar and the Kingdom of Bahrain. At the time of writing (early 2015), a total of 66 species of Odonata have been recorded from the region, including 38 species of Libellulidae. The larvae of all but three of these Arabian Libellulidae species are described and illustrated in Suhling *et al.* (2014). This latter work covers the region of Namibia in southern Africa and none of the three excluded species occurs in that region. Those three species together with *Urothemis edwardsii* (which is included in Suhling *et al.* (2014)) are all of the Arabian members of the Urothemistinae.

The contribution made by this paper is presented in two parts:

I. **Key and general description of the Urothemistinae of Arabia** – Taking features described in Suhling *et al.* (2014) to highlight the identification features of the Urothemistinae of Arabia. *Macrodiplax cora* and *Selysiothemis nigra* are illustrated and described in general terms.

II. **The genus *Urothemis* in Arabia** – The two remaining species are of the genus *Urothemis*. *Urothemis thomasi* is described for the first time. Its congener *U. edwardsii* has been described in detail by Seidenbusch (1995) and Khelifa *et al.* (2013) and is illustrated here. In the interest of brevity, the description of *U. thomasi* provided here concentrates only upon the differences between the two species.

This paper, when used in conjunction with Suhling *et al.* (2014), provides sufficient information for all species of Libellulidae currently known from Arabia to be identified based on final instar larvae and/or exuviae.

I. Key and general description of the Urothemistinae in Arabia

Figure 1 shows headshapes (viewed from above and not to scale) for Libellulidae encountered in the Middle east and North Africa. The features have been emphasised for effect.

Figure 1a Headshape 1 – Libellulinae

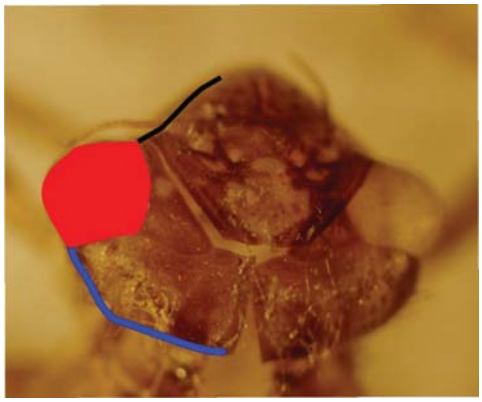


Figure 1b Headshape 2 - Sympetrinae

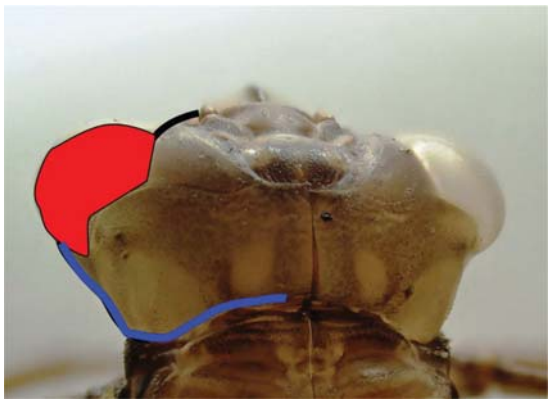


Figure 1c Headshape 3 - *Zygonyx*

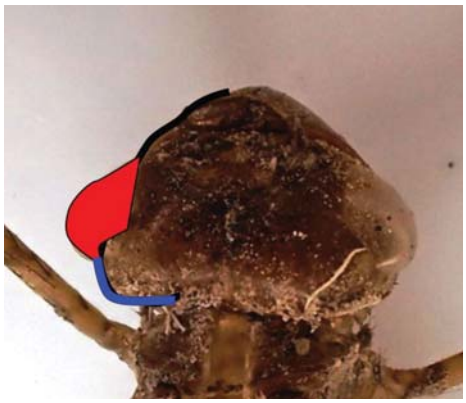


Figure 1d Headshape 3 - Urothemistinae.

- Headshape 1 is unique to the Libellulinae subfamily. The very small eyes (highlighted in red) and parallel head margins (blue)are diagnostic.
- Headshape 2 typical of the other members of the family Libellulidae not featured here with large eyes and rounded margins (blue)
- Headshape 3, with its strong round eyes and strongly incurved head margins, is unique and diagnostic to *Zygonyx*.

Headshape 4, with almost triangular profile and strongly backward pointing eyes, is found in three groups identifiable in Arabia with the following key:

1. Abdomen without dorsal spines.....*Tramea* and *Pantala* (footnote 1)
1'. Abdomen with dorsal spines often very small.....2
2. Dorsal spines not present on abdominal segment (ab. seg.) 9.....Urothemistinae (*Urothemis*, *Selysiothemis* and *Macrodiplax*)
2'. Dorsal spines present on ab. seg. 9.....3
3. Larvae/exuviae <17.0 mm long; distinctive egg shaped abdomen with very compressed anal pyramid.....*Rhyothemis* (footnote 2)
3'. Larvae/exuviae 20.0 mm long; rounded abdomen with prominent anal pyramid *Tholymis* (footnote 2)

Footnote 1: *Pantala* does have small dorsal spines, but only on ab. segs. 2-4; the overall appearance is very similar to *Tramea* although the uniformly black tarsi of *Pantala* are diagnostic. Other features separating *Pantala* from *Tramea* are the very short moveable hook and deep palpal crenations of the former species.
The features above are illustrated in Suhling *et al.* (2014). In addition, *Rhyothemis* exuvia is described in Samways *et al.* (1998).

Footnote 2: The eyes in *Tramea, Pantala* and the Urothemistinae are greater than half head length, eyes in *Rhyothemis* and *Tholymis* are small and less than half head length.

The Urothemistinae can therefore be separated by:

- Headshape type 4)
- Dorsal spines present but absent from ab. seg. 9
- Eyes greater than half the length of the head
- Large size, always in excess of 17.0 mm long

Figure 2 shows all four species of Urothemistinae that have currently been recorded from the Arabian Peninsula. The most striking feature is how distinct *Urothemis thomasi* is from the other three species, with its distinctive colour patterning very strong dark markings on head, thorax and abdomen and minute dorsal and lateral abdominal spines.

Figure 2a *Macrodiplax cora*
Length: 20.2 mm.

Figure 2b *Urothemis edwardsii*
Length 18.2 mm.

Figure 2c *Urothemis thomasi*
Length 19.2 mm.

Figure 2d *Selysiothemis nigra*
Length 17.5 mm.

The regional members of the genus *Urothemis* can be separated from the remaining two genera by the presence of conspicuous and long setae which are best seen on the live larvae but persist on the exuviae (Figure 3).

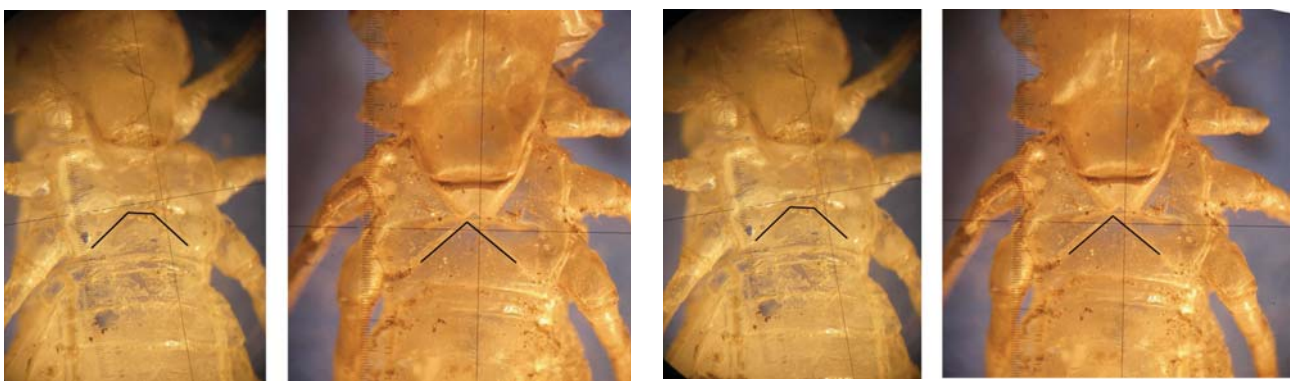
Figure 3a *Urothemis thomasi* larva showing the distinctive setae of the genus.

Figure 3b *U. thomasi exuvia* showing the long setae on the upper surface of the abdomen.

Figure 3c *U. edwardsii* with the long setae on the underside of the abdomen.

The presence of setae in exuviae can be difficult to detect as they can easily be broken. In such cases the triangular or sub-triangular shape of the poststernum is diagnostic within the Urothemistinae (Figure 4).

Figure 4. Poststernum in Urothemistinae – for emphasis shown in black – viewed from the underside.



4a *Macrodiplax cora* (trapezoidal)

4b *Urothemis thomasi* (triangular)

Macrodiplax* and *Selysiothemis are both very mobile, vagrant and migrant, species and are highly salt-tolerant. The former is known from the Dhofar coast and inland desert oases as well as from northern Oman in coastal lagoons. It has even been recorded in a resort swimming pool. *Selysiothemis nigra* has been widely recorded from a variety of habitats over much of Arabia. Both species are known from neighbouring coastal lagoons in northern Oman and probably will be found syntopically in the future. Their exuviae are quite distinct, as shown below.

According to de Fonseka (2000), the larvae of *Macrodiplax cora* had never been described. It was, however, subsequently figured and/or keyed in several publications (e.g. Theischinger & Hawking, 2006; Theischinger & Endersby, 2009, 2014) and appears to be a large exuvia (20.2 mm) with very distinctive straight lateral spines extending at least to the end of the anal pyramid. In the photo provided by Ozono *et al.* (2012), the lateral spines on ab. seg. 9 do not quite reach the apex of the anal pyramid, however, showing that the variability of this feature remains open to study. The sharply pointed nature of the lateral spines on ab. seg. 9 is used in Theischinger & Endersby (2009) (p. 180) to separate *Macrodiplax* from *Urothemis*. Besides, this lateral spine is described as having a slightly S-curved outer edge, whereas the latter is straight in *Urothemis*. Both features match our specimens, which we can therefore ascribe to *Macrodiplax cora* (Figure 5a). The larva of this taxon is also illustrated, without description, by Lieftinck (1962). However, on p. 83, the figure of *M. cora* looks rather different from both that of Theischinger & Endersby (2009) and our specimens. Lieftinck's illustration has convergent lateral spines and a very short anal pyramid (Figure 5c).

In order to support our identification with further evidence, we have compared the exuviae of *Macrodiplax cora* and *Macrodiplax balteatus*, the only other species of this genus, which is found in the southern parts of the USA. The two species are shown in Figure 5 together with Lieftinck's illustration. The specimen of *M. balteatus* shown here was collected in southern Florida and has been identified using Needham *et al.* (2000). The only obvious difference between the two species is that *M. balteatus* is very heavily marked whilst *M. cora* shows a quite uniform light brown. All 17 specimens of *M. balteatus* in DGC's collection show these very strong markings which are not present in *M. cora*. However, the absence of markings cannot be regarded as a diagnostic feature as the *M. cora* specimens may simply have been bleached by the sun. The principal point is that the whole genus is characterised by a large anal pyramid and straight and sharply pointed lateral spines on ab. seg. 9. The identity of the Lieftinck specimen (Figure 5c) is open to speculation.

Figure 5a *Macrodiplax cora*.

Figure 5b *M. balteatus*.

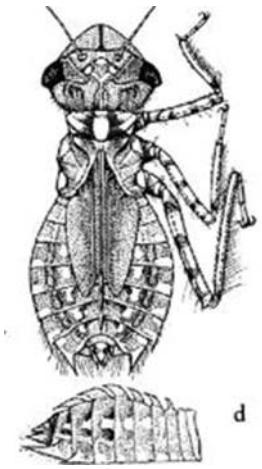


Figure 5c *M. cora* according to Lieftinck (1962).

Selysiothemis nigra has an appearance closer to the genus *Urothemis* with its inward pointing lateral spines and thinner dorsal spines, and can be separated from *M. cora* as shown in Figure 6. The dorsal spines are also quite different (Figures 6c & 6d). *S. nigra* and *M. cora* lack the long setae present in *Urothemis* and both genera have a trapezoidal poststernum. *S. nigra* is a very variable exuvia, with some having strong dark brown markings (Figure 6b) and others suffused with small and poorly defined light brown areas (Figure 7a). Lateral spines may or may not reach the end of the anal pyramid (Figures 6b and 7b). Their size also shows considerable variation, with some specimens exceeding 20 mm in length in, for example, Turkey. Great care should, therefore, be taken in their identification.

Figure 6a. *Macrodiplax cora* abdomen from above. Very straight and parallel long lateral spines on ab. seg. 9, extending to end of anal pyramid..

Figure 6b. *Selysiothemis nigra* abdomen from above. Inwardly curved convergent lateral spines on ab. seg. 9, not extending beyond but sometimes reaching the apex of the anal pyramid.

Figure 6c *M. cora* with wide-based angulated dorsal spines.

Figure 6d *S. nigra* with narrow-based curved dorsal spines.

Figure 7a *Selysiothemis nigra*. Turkish specimen with few pale markings

Figure 7b *Selysiothemis nigra* showing lateral spines on segment 9 reaching end of anal pyramid

The three genera of Urothemistinae in Arabia can be keyed as follows:

1. Abdomen with triangular poststernum (Figure 4b) and long setae on both tergites and sternites, found in the larvae and persisting in the exuviae (Figure 3a).....*Urothemis*
1'. Abdomen with trapezoidal poststernum (Figure 4a) and without setae as above.....2
2. Abdomen with wide-based angulated dorsal spines and long straight parallel lateral spines on ab. seg. 8 & 9.....*Macrodiplax*
2'. Abdomen with narrow-based curved dorsal spines and incurved lateral spines on ab. seg. 8 & 9. Those on ab. seg. 9 convergent.....*Selysiothemis*

II. The genus *Urothemis* in Arabia: comparison of the exuviae of *U. thomasi* and *U. edwardsii*

Two species of *Urothemis* are currently known from Arabia. Whereas the exuvia of *U. edwardsii* has been described in detail by Seidenbusch (1995) and Khelifa *et al.* (2013), the exuvia of *U. thomasi* will be described here for the first time. Figures will highlight the differences between the two species.

General comparison

Figure 8 shows both species of *Urothemis*. The most important difference between *U. edwardsii* and *U. thomasi* is the greatly reduced abdominal spines in *U. thomasi*, both dorsal and lateral. A secondary difference, although perhaps not always reliable (see *Macrodiplax* and *Selysiothemis* descriptions above), is the strength of the colour patterning of *U. thomasi*. In two of the eight specimens of *U. thomasi*, the contrasting dark markings are almost black, as shown on the right of figure 8a and on Figure 8c. In contrast, all 9 specimens of *U. edwardsii* are a uniform brown (Figure 8b). The extensive setae, characteristic of the genus, are clearly seen in Figure 8d.

Figure 8a *Urothemis thomasi* showing variation in colour, one with brown, the other with blackish markings.

Figure 8b *U. edwardsii* with uniform colouring.

Figure 8c *U. thomasi.* Overall view of a larva with black markings.

Figure 8d U. thomasi. Overall view of a last instar larva from above showing the extensive setae characteristic of this genus.

Overall size

Table 1 shows the comparative sizes of the larvae of the two *Urothemis* species found in Arabia. Based upon the material available, *U. edwardsii* in southern Oman is significantly shorter (23.0 %) than those from the Mediterranean coast of Algeria. Even larger specimens (27.0 mm) have been recorded from Lake Bleu, Algeria (B. Samraoui leg.) (Seidenbusch, 1995). Suhling *et al.* (2014) described *U. edwardsii* (p. 74) but did not give any overall size information.

Species	Origin	Dimensions (mm)
U. thomasi	UAE & Northern Oman	Total length = 19.20 ± 0.80; head width = 6.00 ± 0.10
U. edwardsii	Dhofar, Oman	Total length = 18.80 ± 0.80; head width = 6.00 ± 0.10
U. edwardsii	Algeria	Total length = 23.31 ± 0.55; head width = 6.31 ± 0.17

Table 1 – Overall sizes of Urothemis species from various origins

Head

The head of *U. thomasi* is much more strongly marked than *U. edwardsii* and shows a large and well-defined pale spot in the middle in dorsal view (Figure 9). See also Figures 2b and 2c, and 8a and 8b.

Labium

Figure 9a *Urothemis thomasi*

Figure 9b *U. edwardsii*

The labium of the two *Urothemis* species is very similar (Figure10: dorsal view; Figure11: ventral view). The most significant difference is that *U. edwardsii* has more extensive dark spotting on both the labial palps and the underside of the prementum. This dark spotting can be seen as well in figure 12, which also shows the long antennae with slender tapering segment 7, identified by RS as an additional important feature for the genus.

Figure 10a *Urothemis thomasi*: labial mask viewed dorsally

Figure 10b *Urothemis edwardsii*: labial mask viewed dorsally

Figure 11 Labial masks viewed ventrally - *Urothemis thomasi* (left) and *U. edwardsii* (right)

Figure 12a *U. thomasi* - Palpus viewed from front

Figure 12a *U. thomasi* - Palpus viewed from front

Thorax

The thorax is identical for both species, except for the extensive brown/black markings in *U. thomasi* as shown in Figure 8.

Abdomen

All specimens of *U. edwardsii* have a uniformly brown abdomen with faint and indistinct brown markings only visible after the abdomens have been cleaned (Figure13a). Contrarily, *U. thomasi* has very extensive dark brown to black markings on the upper surface of the abdomen (Figure13b). The markings are similar to but much stronger and more extensive than those on *Sympetrum fonscolombii*, to which the abdomen bears a striking resemblance (Figure13c). However, the *S. fonscolombii* larva or exuvia can easily be separated from *Urothemis* by its smaller size, the head shape and the absence of long setae. In addition the dark markings are only present on ab.seg. 6-10 on *S. fonscolombii* whereas they occur on ab.seg. 5-10 on *U. thomasi*.

Figure 13a. *Urothemis edwardsii*

Figure 13b. *U. thomasi*

Figure 13c. *Sympetrum fonscolombii*

As mentioned above, markings can be very unreliable in exuviae and structural features should always be relied upon for identification as follows:

Dorsal spines. Present on abdominal segments 3 to 8 in both species, but well defined in *U. edwardsii* and quite residual in *U. thomasi* (Figure14a, b).

Figure 14a *Urothemis thomasi,* dorsal spines, lateral view

Lateral spines. Present on abdominal segments 8 & 9 in both species, but well defined in *U. edwardsii* and quite residual on S8 and small on S9 in *U. thomasi* (Figure 15a, b).

Figure 14b *U. edwardsii*, dorsal spines, lateral view.

- ***Anal pyramid.*** The cerci ratios are similar in both species, so we can add little to the information provided by Khelifa *et al*. (2013).

Figure 15 *Urothemis edwardsii*, lateral spines and anal pyramid

Figure 15b *U. thomasi*, lateral spines and anal pyramid

Conclusion

The initial features which drew the attention of DGC and RS to the separation of *U. thomasi* from other exuviae collected from the region have proved to be correct. The residual abdominal spines combined with the large size and the very distinctive dark markings clearly separate the species. As for the genus *Urothemis*, the long setae found on all parts of the larva and which persist in the exuvia appear to be diagnostic and the triangular shaped poststernum is diagnostic within the Urothemistinae.

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We would like to thank Philippe Lambret for his dedication in rearing to emergence a live larva of *U. thomasi*, which confirmed the identification of the species. Our thanks also to Christian Monnerat for supplying the live larvae from Oman and sending these to CB. Finally, thanks to Anthony Stoquert who replaced DGC at short notice on the second field trip and was responsible for collecting the exuviae and the larva of *U. thomasi* that was subsequently bred out.

Finally we would like to thank Gary Feulner for his extremely helpful comments and amendments which have been incorporated.

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A record of the Great Eggfly *Hypolimnas bolina* (Linnaeus, 1758) from Masirah Island, Oman and a summary of previous records from Arabia

by Victor Hitchings and Oscar Campbell

Abstract

On a visit to Masirah Island, Oman, observations were made of the striking butterfly *Hypolimnas bolina*, the Great Eggfly, at three locations over a four-day period in early October 2014. They were observed apparently making landfall at the south of the island and nectaring and basking in an overgrown orchard and hotel gardens in the north of the island. This species has previously been recorded from four other locations in Oman and two in the United Arab Emirates, with the most recent report prior to 2014 being in 1993. Three possible origins for the 2014 individuals are discussed: 1) immigrants from Socotra Island, either by natural dispersal or displacement by a tropical storm either directly over the sea or via southern Oman; 2) immigrants from the Indian subcontinent; and 3) accidental introduction with imported plants.

Figs. 1 & 2 *Hypolimnas bolina*, Great Eggfly, females nectaring on *Prosopis juliflora*, Masirah, 5th October 2014. © Oscar Campbell

Introduction

Whilst on a visit to Masirah Island (off the south-east coast of Oman) from 4th to 7th October 2014, primarily to look for migrating birds, OC was surprised to find a very large, distinctively patterned butterfly that was not immediately recognised. Individuals were recorded at three sites. At two of those sites, other butterflies, initially taken to be examples of the male Diadem *Hypolimnas misippus* were also recorded. Photographs were taken and reference to Larsen (1984) on return to Abu Dhabi immediately showed that the 'mystery' species involved was the female of *H. bolina*, the Great Eggfly (also known as Giant Eggfly, Common Eggfly), and that the other butterflies associating with it were, in fact, not *H. misippus* but males of *H. bolina*. The observations made are detailed below and previous records of *H. bolina* in Oman and the United Arab Emirates are discussed, along with possible origins of the Masirah individuals. Photographs of the Masirah individuals are included but, unfortunately, only images of the females were obtained (Figs. 1 & 2).

Observations

The first example of *H. bolina* observed was at 1300 on 4th October at Ra's Abu Ra's (20.16°N, 58.63°E) the southernmost point of Masirah and 60km SSW from Hilf, the island's main settlement. It was first located using a telescope and appeared to be arriving from the sea. A little later another individual, more distant but seemingly the same species, was noted apparently making landfall in the same manner.

On 5th October at least three female *H. bolina* were seen in an overgrown orchard by the water treatment plant at Hilf near the northern tip of Masirah (20.619°N, 58.869°E). The insects were nectaring on shrubby *Lantana* bushes and basking in the early morning sun. Several males were also present and were observed on occasion to chase the obviously larger females. Insects nectared with their wings closed but also regularly flashed them open, revealing the uppersides. Butterflies were seen at this location daily until 7th October, on which date OC left Masirah. A prior early morning visit had been made to this site on 4th October; no butterflies were observed but it is

Hypolimnas bolina (Great Eggfly)

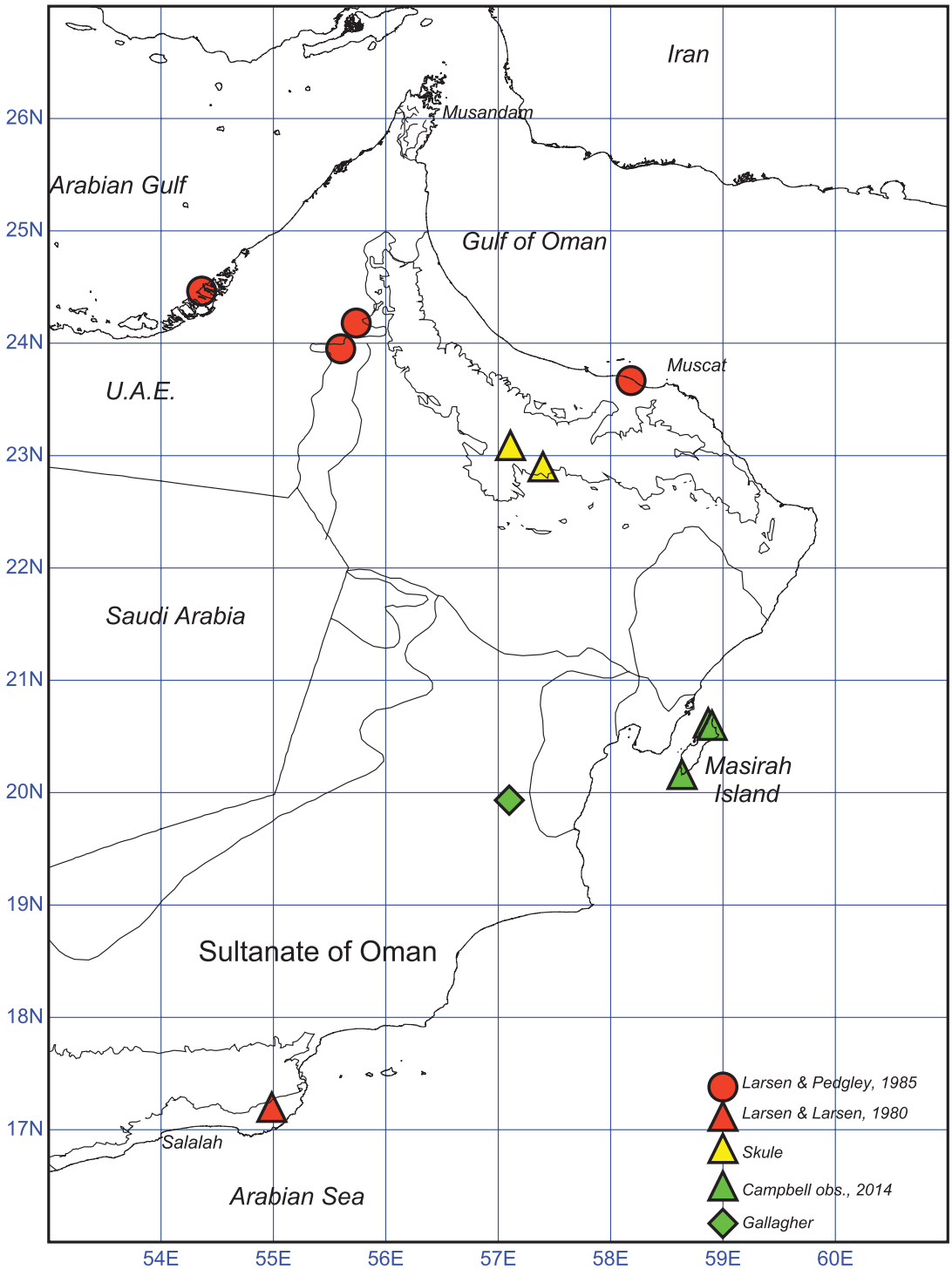

Fig. 3 Distribution records of *Hypolimnas bolina* in Oman and the UAE, including the 2014 observations.

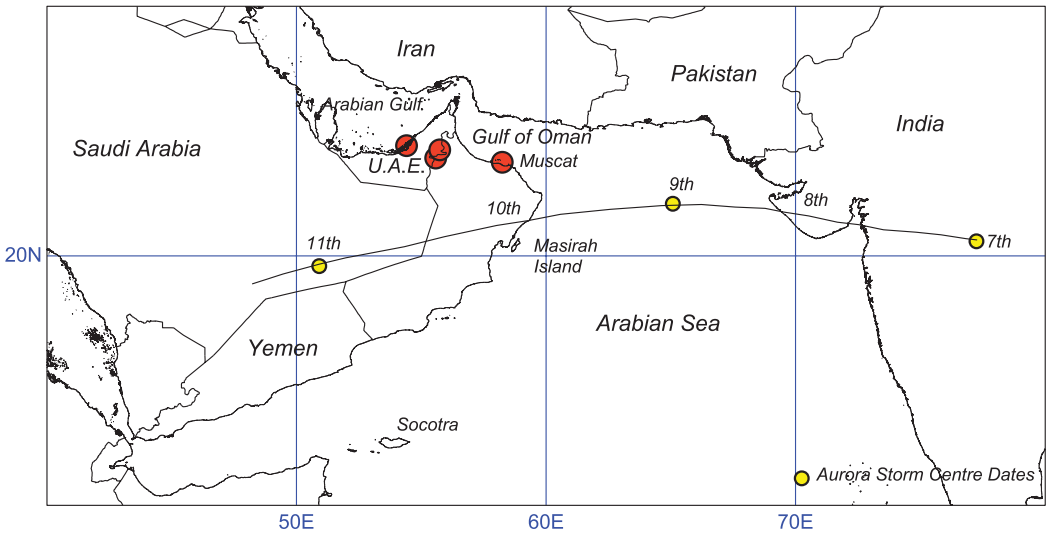

Fig. 4 Location of *Hypolimnas bolina* specimens blown in by storm Aurora in August 1983 (red dots) and the storm track (yellow dots) with dates (after Larsen & Pedgley, 1985).

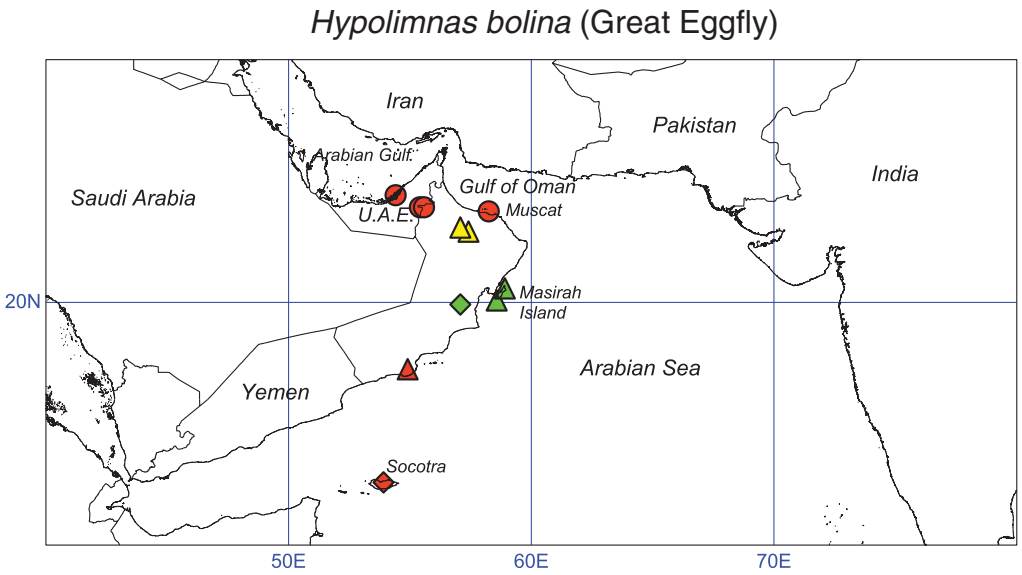

Fig. 5 Distribution of the historical records of *Hypolimnas bolina* in relation to Socotra (red diamond).(For legend see Figure 3)

quite possible they were present. Additionally, on 5th October another female was observed and photographed nectaring on the sunny edge of an overgrown *Prosopis juliflora* approximately 300m from the *Lantana* clump (Plates 1 and 2). This area was searched on subsequent dates until 7th October but butterflies were not seen in this area again.

Finally, on 5th October, at least six *H. bolina* (males and females) were located within the grounds of Masirah Island Resort, a recently developed hotel on the north-east side of the island (20.598°N, 58.903°E) and 4km ESE of the orchard at Hilf. They were actively nectaring on ornamental plants, in the company of small numbers of the Painted Lady *Vanessa cardui*. This location has been observed to hold migrant butterflies in previous autumns (for example up to 40 *V. cardui* in September 2009; OC *pers. obs.*).

As far as is known, there were no further reports of *H. bolina* on Masirah later in autumn 2014 or in 2015 (J. Eriksen, *in litt.*) although observer coverage is likely to be have been very low. In 2016, OC visited Masirah again from September 11th to 16th. Four full days were spent in the same sites outlined above but, despite specific searches being made repeatedly, no individuals of *H. bolina* were noted. Interestingly, however, at least two examples of male *H. misippus* were located, defending territories in the orchard at Hilf. No females were recorded.

Subspecies identification and distribution

Hypolimnas bolina is widely distributed in the Oriental and Australasian Regions, as well as on the islands of Madagascar, Mauritius and Socotra in the Afrotropical Region.

D'Abrera (1980) lists two major subspecies of *H. bolina*:

The nominate *Hypolimnas bolina bolina* (Linnaeus, 1758), found in the Australasian Region.

Subspecies *Hypolimnas bolina jacintha* (Drury, 1773), sometimes referred to as the Jacintha Eggfly, found from India to Taiwan (in the Oriental Region) and in Mauritius.

According to Corbet & Pendlebury (1992) and D'Abrera (1985), *jacintha* males are distinguishable by a "row of post-discal white spots on the recto surface". These spots are absent in the males of *bolina*.

An overlap of range between these two subspecies occurs in peninsular Malaysia and Singapore where both subspecies fly. Eighteen further subspecies of *H. bolina* are known, mostly from Australia and the Pacific Islands, but are not considered here.

Previous Records of *H. bolina* in Oman and the UAE

There are eight previous records of *H. bolina* from Oman and the UAE. These are mapped (Fig. 3) and summarised below.

A sighting of *H. bolina* was reported from Dhofar in Larsen & Larsen (1980) in October 1979 from 'above Rakhyut'. The butterfly was identified as a female but no specimen or photographs are available to ascertain the subspecies. Larsen (1983), relying on Elliott (1978) believed it to belong to subspecies *jacintha*.

Larsen & Pedgley *(1985)* reported records of *H. bolina jacintha* after being 'blown into Arabia' by tropical storm Aurora in August 1983. See discussion below, and Fig. 2.

H. bolina specimens were taken by Bjarne Skule *from Wa*di Ghul and Wadi Muaydin in Oman in May and June 1993 (respectively) *(Hitchings* & Skule, 2004). All of the specimens taken are female and cannot be identified to subspecies level.

H. bolina is represented in the national reference collection at the Natural History Museum in Muscat. Five specimens were collected during a survey visits by Michael D. Gallagher in Jaaluni in the Al Wusta Region of Oman (Hitchings, 2005). The dates vary from 1st September, 3rd October and 27th November 1992. No subspecies information is currently available.

Larsen & Pedgley (1985) reported records of *H. bolina* from four localities in Oman and the UAE. These observations were particularly interesting as it was surmised that the insects had been 'blown into Arabia' by tropical storm Aurora in August 1983 to four localities (see Figure 4): two in Oman (Seeb, Muscat and inland in the north-west of the country near the Buraimi oasis) and two in the UAE (Abu Dhabi island and near Al Ain Zoo). The Seeb record was a single individual, all others involved 'several'. It is interesting to note that Buraimi, Oman and Al Ain, UAE are adjacent to one another and that all records date from a very narrow time period (12th to 16th August) and within days of Storm Aurora crossing eastern Arabia westwards from the Indian subcontinent on 10th to 11th August. In this instance, based on analysis of specimens taken and, as would be expected given the origin of the storm concerned, the butterflies were identified as *Hypolimnas bolina jacintha*, and hence presumably originated from India.

Discussion

All of the photographs available from the 2014 Oman records are of female *H. bolina* and therefore not sufficient to permit identification to subspecies level. The closest known location to Masirah where *H. bolina* is resident is on the Socotra Islands, Yemen (Larsen & Larsen, 1980; Fric & Hula, 2013) some 1,000 kilometres southwest of Masirah but 390 kilometres from mainland Yemen and 450 kilometres from neighbouring Dhofar, Oman. Despite enquiries, it has not been possible to ascertain the subspecific identity *H.bolina* on Socotra where it appears to be rather poorly known.

Whilst it is presently impossible to go beyond informed speculation, it is interesting to consider the possible origin of the examples of *H. bolina* on Masirah.

If Socotra was the source of the Masirah butterflies, three possibilities may account for this:

1. The butterflies reached Masirah aided by the prevailing south-westerly winds that blow from April to September or early October over the northern Indian Ocean (Fisher & Membery, 1988). Evidence that this may be the case are the two individuals observed apparently arriving at the southern tip of the island on 5th October. However, such winds are an annual and marked phenomenon across the northern Indian Ocean and, if butterflies are prone to displacement by such 'normal' conditions, one might expect them to be more regular on Masirah and southern Oman in general.

2. They were blown from to Masirah from Socotra by a tropical storm. As *Hypolimnas bolina jacintha* has been recorded as storm-blown individuals to Oman and the UAE in 1983 (Larsen & Pedgley, 1985) it is reasonable to consider this possibility. Furthermore, in 2014 the North Indian Ocean Cyclonic Storm Nanauk, tracked over Socotra and north-eastwards from 7th to 14th June (see Figure 6). The five month interval between the storm and the sightings would be ample time for *H. bolina* to establish breeding populations. However, if this is the case, it must be noted that there have been no further sightings on Masirah Island in 2014 and 2015 (although this may be a function of a lack of observers) and the species, although searched for, was apparently absent by September 2016. Hence, any breeding population, if indeed one was established at all, did not persist.

3. They migrated from Socotra to mainland Yemen/Dhofar and then on to Masirah. Records of this species in southern Oman indicate this is a possibility. However, it is likely that many individuals would need to arrive in southern Oman to account for the handful observed on Masirah and there have been no records in southern Oman since 1980. Again, however, a lack of sightings in 2014 may simply reflect the lack of observers.

Possibilities for an origin other than Socotra include:

4. The butterflies had a natural Indian origin, arriving on Masirah at some point prior to October 2014.

5. The butterflies were introduced with imported plants for the gardens, for example at the recently constructed Masirah Island Resort.

Possibility 5 is difficult to evaluate without knowing the identity and source of ornamental plants used on Masirah, but it offers no explanation for the apparent arrival of individual *H. bolina* by sea, from the south, as observed in this instance. Possibility 4 is hard to discount in the absence of knowledge of the subspecific identity of the butterflies but seems unlikely, at least in the six month period prior to the sightings, given the prevailing wind direction over the northern Indian Ocean and the absence of any storm on a similar track to Storm Aurora.

It has been recently established that the dragonfly

Fig. 6 Image of Cyclonic Storm Nanauk near peak intensity on 12th June 2014. Image by NASA, MODIS - NASA WorldView, Public Domain, https://commons.wikimedia.org/w/index.php?curid=33384149

Pantala flavescens crosses the entire tropical Indian Ocean routinely (Anderson, 2009) from India (or possibly from even further to the north and east; Hobson *et al*, 2012) to East Africa, using north-east tail winds established as the Inter-Tropical Convergence Zone passes south from mid-October onwards. For this reason, we deem the possibility of *H. bolina* arriving on Masirah in autumn 2013 or the winter following this and then colonising, at least temporarily, is at least plausible.

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We are extremely grateful to Gary Feulner for completing a comprehensive edit of a first draft of this paper and for many insightful comments that have greatly improved the text. Jens Eriksen provided information on his observations on Masirah in late autumn 2014 and subsequently. Richard Porter, Vladimir Hula and Kay van Damme all promptly answered queries concerning *H bolina* on Socotra. Gillian Ensor accompanied OC during both visits to Masirah and exhibited both enthusiasm and patience in abundance.

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Spiders of the United Arab Emirates: An Update (2016)

by Binish Roobas and Gary R. Feulner

Abstract

The introductory catalogue of UAE spiders (Feulner & Roobas 2015) is updated here with ten illustrated records of newly recognised species. Two earlier records are revised. Photographs are presented for two species previously recorded by others but not illustrated in the introductory catalogue. Additional information is provided about three species that have proved to be more widespread and adaptable than was initially recognised.

The spider species discussed in this paper are listed immediately below. The key indicates the nature of the discussion. As in the introductory catalogue, common names proposed by the authors are shown in *italics*.

	Scientific Name	Common Name
	Family Agelenidae	Funnel Weavers / Sheet Weavers
+	**cf. *Benoitia lepida*** (O. P.-Cambridge, 1876)	*Mid-East Funnel Weaver*
	Family Araneidae	Orb-Web Spiders
*	***Argiope trifasciata*** (Forsskål, 1775)	Banded Argiope
*	***Argiope* sp. B**	*Cemetery Argiope*
+	***Cyrtophora* cf. *citricola*** (Forsskål, 1775)	Tropical Tent-Weaver, Six-Humped Dome Weaver
*	***Eriovixia* cf. *excelsa*** (Simon, 1889)	Dark Bird Dropping Spider
	Family Eresidae	Velvet Spiders
+	***Stegodyphus* cf. *nathistmus*** Kraus & Kraus, 1989	*Veiled Velvet Spider*
*	***Stegodyphus* sp.**	*White-Backed Velvet Spider*
	Family Oxyopidae	Lynx Spiders
*	***Peucetia* sp.**	*Abutilon Lynx Spider*
	Family Pholcidae	Daddy Long-Legs
†	***Artema* cf. *atlanta*** Walckenaer, 1837	Giant Daddy Long-Legs
*	***Artema doriai*** (Thorell, 1881)	Doria's Giant Daddy Long-Legs
	Family Salticidae	Jumping Spiders
§	***Hasarius adansoni*** (Audouin, 1826)	(see Wesolowska & van Harten 2011)
§	***Hyllus dotatus*** (Peckham & Peckham, 1903)	(see Wesolowska & van Harten 2010)
	Family Sparassidae	Huntsman Spiders
*	***Olios* cf. *iranii* [B]** (Pocock, 1901)	*Orange Huntsman*
†	**Sparassidae gen. sp. C**	[= *Lachesana insensibilis*, Zodariidae]
	Family Theridiidae	Cobweb Weavers
*	***Latrodectus geometricus*** Koch, 1841	Brown Widow
*	***Latrodectus* cf. *renivulvatus*** Dahl, 1902	Inland Button Spider
	Family Zodariidae	Ant-Eating Spiders
*	***Lachesana insensibilis*** Jocqué, 1991	*Bristly Arabian Zodariid*

Key

* New record
† Revised record (from Feulner & Roobas 2015)
§ Previously recorded species is illustrated here
\+ Additional information is presented

Introduction

The introductory catalogue of UAE spiders published in ***Tribulus*** Vol. 23 has so far served its purpose to encourage greater attention to the local spider fauna and provide a foundation for further study. Since publication, several additional spider species have been 'discovered' in the UAE, an unknown species has been identified, a suspected species has been confirmed to be present, several species previously recorded by others have been observed and photographed by the authors, and additional information has been obtained about the habits, habitats and distribution of several other species. Those results are presented below.

It should be noted, however, that this update does not exhaust the number of still unidentified species represented in our own photographs and collections, much less those that remain to be recognised. To facilitate general reference and ongoing study the authors have also established a website where UAE spider records and basic information will be maintained. Observers wishing to contribute are invited to visit: www.UAESpiders.org.

Fig. 1a *Argiope trifasciata*: Underside of a female in a *Salvadora persica* bush at Jimi Oasis, Al-Ain. (BR)

Fig. 1b *Argiope trifasciata*: Upperside of the female shown in Fig. 1a. (GRF)

New Records

ARANEIDAE

Argiope trifasciata. This large orb-weaver is found in warm regions worldwide. Its presence in the UAE is not surprising, although it is probably restricted to mesic environments. We found a large female in Jimi Oasis in Al-Ain, where the spider had constructed a web in a low hollow in the north-east side of a large shrub of *Salvadora persica*. The web was vertically oriented, ca. 30 cm in diameter and centred ca. 50 cm from the ground. Although the shrub was teeming with butterflies (especially the Blue Spotted Arab *Colotis phisadia*), there were no butterflies or other prey in the web.

Our identification of this well known species relies on comparison of details of the upperside and underside markings (Figs. 1a and 1b) with numerous published photographs and other illustrations. Our photos confirm our earlier judgment that the pattern of the underside of *A. trifasciatus* is very similar to the underside of another UAE species that we have called, for convenience, *Argiope* sp. A, but the colouration of the uppersides and the gross shapes of their abdomens are very different.

Fig. 2a *Argiope* sp. B: Upperside of the female seen in an East Coast plantation. The sheet-like form of the stabilimentum could be an indication that this spider is not yet mature. (GRF)

Fig. 2b *Argiope* sp. B: Underside of the spider shown in Fig. 2a, *in vitro*. (GRF)

***Argiope* sp. B**. The relatively small female Argiope shown in Figs. 2a and 2b was encountered only once, in an abandoned and partially overgrown cemetery within the plantations at Mirbah, Fujairah on the UAE's East Coast. The colour pattern of the underside is very similar to that of *A. aemula*, *A. pulchella*, *A. versicolor* et al. (see discussion in Feulner & Roobas 2015, at p. 20 and Fig. 7.2). The upperside, however, is completely different. The relatively small size of this specimen and its construction of a sheet-like stabilimentum suggest that it could be a juvenile, but from our experience we would not expect the colour pattern of a juvenile *Argiope* to differ greatly from that of the adult.

***Eriovixia* cf. *excelsa*.** The tropical Asian and African genus *Eriovixia* is characterised by spiders having a squat body with a hump (sometimes greatly elongated) at the rear of the dorsal abdomen. The species illustrated in Figs. 3a and 3b was common in a coastal plantation at Mirbah, Fujairah in mid-November 2015, where we found the spiders active in late afternoon, when they were commencing to build their nightly orb webs. The spider in our photos resembles online (Google) images of *E. excelsa*,

Fig. 3b *Eriovixia* cf. *excelsa*: The same spider shown in Fig. 3a, seen in natural light. (GRF)

Fig. 3a *Eriovixia* cf. *excelsa*: Profile of a female on a 'tightrope' web in a coastal Fujairah plantation, taken with flash. (BR)

Fig. 3c *Eriovixia* cf. *excelsa*: Dorsal view of the spider shown in Fig. 3a and 3b. (BR)

which are in substantial agreement. *E. excelsa* is a common Indian garden spider which it would not be unreasonable to find on the UAE's East Coast. Characteristic features are the overall shape, the pale colouration and the presence of large, dark, oblong but irregular marks on the posterior flanks of the abdomen. We wish to thank Apurv Jadhav for suggesting the generic identification of *Eriovixia* from our photographs.

ERESIDAE

***Stegodyphus* sp.** The male *Stegodyphus* shown in Figs. 4a and 4b was found by Angela Manthorpe of the Dubai Natural History Group in a large, flowering *Calotropis procera* in the Sharjah desert, where she noticed its dense, brown, compact web in the fork of two stems shaded by a large leaf. The nature of the web suggested that the occupant might be a *Stegodyphus*, but the authors were surprised when a male spider emerged, and equally surprised by its colouration – a bright white dorsal abdomen and contrasting black margins, brown-banded legs, a full "face mask" and dark chelicerae – all of which differ greatly from the patterns seen in UAE females of *Stegodyphus* cf. *lineatus*, a pan-Eremic spider known to be widespread in the sand deserts of the UAE (compare Figs. 17.1 to 17.3 in Feulner & Roobas (2015)).

Stegodyphus species are variable in colouration but basic patterns have been identified that seem to be templates for species and species groups (Kraus & Kraus 1989). We consider it unlikely, therefore, that the spider in Figs. 5a and 5b represents the male of *S. lineatus* (which, however, we have not seen). For the same reasons, and because of its habitat, we consider it unlikely to be the male of *Stegodyphus* cf. *nathistmus*, a species known from various sites in the Hajar Mountains of the UAE.

A more likely hypothesis, we think, is that it represents a third species, possibly a representative of the *S. dufouri – S. pacifica* complex, of which many records exist from across North Africa to Aden, and from north-west India, but of which scattered records also exist from Iran (Kraus & Kraus 1989, Zamani et al. 2015). The dorsal abdominal colour patterns shown in Kraus & Kraus (1989) lend general support to this hypothesis. For both *S. dufouri* and *S. pacificus*, the pattern shown for the dorsal abdomen consists of a white central shield of varying width, with serial flame-like projections of the margin into a black or darker lateral border.

OXYOPIDAE

***Peucetia* sp**. The green lynx spiders shown in Figs. 5a and 5b were abundant in a large clump of *Abutilon pannosum* (Malvaceae) shrubs growing near the bottom of a scree slope in Wadi Safad, Fujairah, across the wadi from a large traditional plantation. On a visit in mid-September 2016, we found a spider near the end of nearly every erect stem, sheltered under the broad leaves. All were similar in appearance, featuring faint but pervasive white spotting on the green abdomen, and in that respect different from the *Peucetia* species previously encountered, which we recorded as *Peucetia* cf. *viridana*. Another species, *P. viridis*, is known from Algeria, South Africa, the southern Iberian peninsula, Yemen and Socotra, and elsewhere in the Middle East (Santos & van Harten 2002), and it would not be surprising to find it in the UAE, but *P. viridis* closely resembles *P. viridana*, so the spiders found in Wadi Safad are considered likely to represent a third species, as yet undetermined.

Fig. 4a *Stegodyphus* sp.: Frontal view of a male found on a shrub of *Calotropis procera* in the Sharjah desert. The colour pattern suggests it is likely to represent a species new to the UAE. (BR)

Fig. 4b *Stegodyphus* sp.: Dorsal view of the male shown in Fig. 4a. (BR)

Fig. 5a *Peucetia* sp.: Dorsal view of a female found in a large clump of *Abutilon pannosum* in Wadi Safad, Fujairah. The colour pattern suggests it is likely to represent a species new to the UAE. (BR)

Fig. 5b *Peucetia* sp.: Oblique view of a second female from the same shrub as Fig. 5a. (BR)

PHOLCIDAE

Artema doriai. The large pholcid common in the mountains and peri-montane areas of the UAE (Fig. 6; see original Figs. 44.1, 44.2, 44.3) was listed in the introductory catalogue as *Artema* cf. *atlanta*. However, specimens collected from Wadi Wurayah by Siegfried Huber have since been authoritatively identified as *S. doriai* (J. Judas, *pers. comm.*). *A. doriai* is also known from Iran, where Alireza Zamani (*pers. comm*.) advised us that in recent years it has been found to be more widespread than previously thought. This may explain why the common UAE species does not conform to the characterisation of *A. atlanta* as a synanthropic species (Huber & Warui 2012). Possible conflation of the two species could also explain the discrepancies in geographical range mentioned in our original discussion.

SPARASSIDAE

Olios* cf. *iranii (B). This medium sized huntsman spider (Figs. 7a and 7b) is one of eight species of Sparassidae found in the UAE to date, and the second *Olios* species. Both UAE *Olios* species appear to belong to the *Olios iranii* group but a more definitive identification must await a revision of that group (M. Moradmand, *pers. comm*.). The first species was discussed in the introductory catalogue as *Olios* cf. *iranii*, and was found in large numbers in reedbeds in plantations on the outskirts of Dubai. For clarity, it is now preferable to refer to the earlier-recorded species as *Olios* cf. *iranii* (A).

The second species, introduced here as *Olios* cf. *iranii* (B), has been found in two disparate environments: (i) a cement electrical equipment room on Sharjah's Al-Noor Island, a man-made island within Khalid Lagoon, in spring 2016, and

Fig. 6 *Artema doriai*: This large daddy long-legs is one of the most common spiders encountered in the mountain wadi environment of the UAE. It was tentatively identified in Feulner & Roobas (2015) as *Artema* cf. *atlanta*, but it has since been definitively identified based on specimens collected by Siegfried Huber from Wadi Wurayah, Fujairah. (GRF)

Fig. 7a *Olios* cf. *iranii* (B): Frontal view of a female from Al-Noor Island, Sharjah. (BR)

Fig. 7b *Olios* cf. *iranii* (B): Dorsal view of the spider shown in Fig. 7a. (BR)

(ii) a coastal plantation in Fujairah, on the UAE's East Coast, in summer 2016. It is distinguished visually from *Olios* cf. *iranii* (A) by its orange-coloured abdomen (both dorsally and ventrally) and by its pale face and dark brown, hairy chelicerae (versus a black face and smooth black chelicerae in *Olios* cf. *iranii* (A)).

THERIDIIDAE

Latrodectus geometricus. *L. geometricus* was mentioned in the introductory catalogue, in the discussion of *L. dahli*, as a species considered likely to be present on the basis of photographic evidence and general range, but that had not yet been confirmed. Publication of the catalogue prompted confirmation from two residential locations in Dubai, courtesy of Joanna Pugolis and Anelisa Lambert. Members of the genus *Latrodectus* are notoriously difficult to identify, but confirmation was possible in the case of *L. geometricus* because the egg case is distinctive: the small white or off-white sphere is profusely studded with tiny spikes or pimples. Both ladies obligingly took photos of the spiders and their egg cases in the service of science (Figs 8a, 8b and 8c). Joanna found hers under furniture in an unused room in her house. Anelisa's found its way into her home with her daughter's bicycle, brought in from the garden over the summer.

Although the normal adult colour of *L. geometricus* is a uniform brown with a red-orange ventral hourglass, adults sometimes retain their juvenile coloration into maturity, displaying more colourful patterns of stripes on the abdomen and making identification more difficult.

Latrodectus* cf. *renivulvatus. Roobas found the female *Latrodectus* shown in Figs. 9a, 9b and 9c in a small, untidy web under an aloe-like

Fig. 8a *Latrodectus geometricus*: A Brown Widow female, a brown spider with a red-orange hourglass shape on the underside of her abdomen. (Picture by Anelisa Lambert)

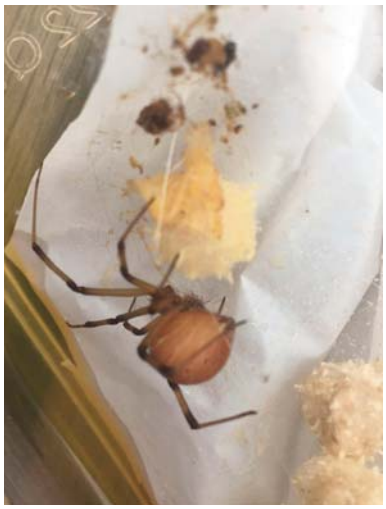

Fig. 8b *Latrodectus geometricus*: Posterior view of a female showing the fully mature colour. In juveniles and some adults, the dorsal abdomen may be marked with diagonal white bands. (Picture by Joanna Pugolis)

Fig. 8c *Latrodectus geometricus*: The distinctive spikey, spherical egg cases of the Brown Widow. (Picture by Joanna Pugolis)

Fig. 9a *Latrodectus* cf. *renivulvatus*: Dorsal view of a female from Al Noor Island, Sharjah. (BR)

Fig. 9b *Latrodectus* cf. *renivulvatus*: Posterior dorsal view of the same spider showing the red medial band accented by a pair of diagonal white streaks. (BR)

Fig. 9c *Latrodectus* cf. *renivulvatus*: Underside view of the same spider, in vitro. (BR)

ornamental plant in a small plot on Al-Noor Island, a man-made island in Khalid Lagoon, Sharjah. The island is landscaped with exotic plants and devoted to outdoor cultural activities, including sculpture and a butterfly garden. From the appearance of the web, Roobas expected a *Latrodectus* species, but he was surprised to see an unfamiliar one.

A review of the discussion and numerous images in Knoflach & van Harten (2002) and other references led us to the conclusion that the spider in question is most likely *L. renivulvatus*, although it is somewhat less colourful than many of those images and may not be fully adult. In particular, the dorsal abdomen is marked anteriorly by transverse recurved white stripes and posteriorly by a red-orange medial band with slightly serrated margins. In our specimen, the underside shows no contrasting coloration.

Latrodectus renivulvatus is known from sub-Saharan Africa as well as Saudi Arabia and Yemen (Knoflach & van Harten 2002), a distribution based on which, from our experience to date, it is not surprising to find it in the UAE.

ZODARIIDAE

***Lachesana insensibilis*.** The bristly, sand-dwelling species listed in the introductory catalogue as "Sparassidae gen. sp. C" (Figs. 10a and 10b) was subsequently recognised by Yuri Marusik as belonging to the Zodariidae and was identified by Majid Moradmand, who examined a specimen, as *Lachesana insensbilis*. The type specimen is from Saudi Arabia and so far only males are known, possibly because the females remain in their burrows and do not wander like males (M. Moradmand, *pers. comm.*). *L. insensibilis* is an atypical zodariid, being large, pale, sand-dwelling and spiny (Jocqué 2011, Jocqué & Dippenaar-Schoeman 2007). Its scientific name refers to the apparent lack of certain specialised sensory organs.

Revised Records

PHOLCIDAE

Artema* cf. *atlanta. The large pholcid common in the mountains and peri-montane areas of the UAE was listed in the introductory catalogue as *Artema* cf. *atlanta*. However, specimens collected from Wadi Wurayah by Siegfried Huber have since been authoritatively identified as *S. doriai* (J. Judas, *pers. comm.*), a species also known from Iran (see above, under "New Records"). This may explain why the common UAE species does not conform to the characterisation of *A. atlanta* as a synanthropic species (Huber & Warui 2012). The occurrence of *A. atlanta* in the UAE must now be considered unconfirmed.

Fig. 10a *Lachesana insensibilis*: This bristly male, found wandering in the desert at night, was at first tentatively identified as a sparassid but has proved to be an atypical zodariid. (BR)

Fig. 10b *Lachesana insensibilis*: Dorsal view of the spider shown in Fig. 10a. (BR)

SPARASSIDAE

Sparassidae gen. sp. C. The bristly species listed in the introductory catalogue as "Sparassidae gen. sp. C" is not, in fact, a sparassid. It was subsequently recognised by Yuri Marusik as belonging to the Zodariidae and by Majid Moradmand, who examined a specimen, as *Lachesana insensbilis*, the type specimen of which is from Saudi Arabia. It is, however, an atypical zodariid. See also the discussion above of *L. insensibilis*, under "New Records").

New Illustrations

SALTICIDAE

Hasarius adansoni. *Hasarius adansoni* was first recorded from the UAE by Wesolowska & van Harten (2011). It was observed by Roobas on the grounds of Emirates Towers and a photograph of the male is presented here (Fig. 11). Roobas has also found it to be common on Al-Noor Island, a man-made island in Sharjah's Khalid Lagoon, landscaped and devoted to leisure activities.

Hyllus dotatus. *Hyllus dotatus* was first recorded from the UAE by Wesolowska & van Harten (2010) (as *Evarcha dotata*). It was observed by the authors at a coastal plantation and photographs of the male (Figs. 12a and 12b) and female (Fig. 12c) are presented here. It is worth mentioning that, although this species is relatively distinctive because of its large size, we nevertheless found it challenging to distinguish between females of *H. dotatus* and the more common *Plexippus paykulli*.

Additional Information

AGELENIDAE

cf. *Benoitia lepida*. We had previously observed this species only in rocky environments in the Hajar mountains of the UAE and Northern Oman. We have since found it common on firm sand on the outskirts of Ain Al-Faydhah. There it made its sheet webs close to the ground, under the cover of spreading *Zygophyllum* shrubs (Fig. 13a) and among the bases of individual reed stems within dense stands of *Phragmites australis*. During a late September 2016 visit, the spiders were active in mid-afternoon (Fig. 13b) and a small number of pendant egg cases were observed.

ARANEIDAE

Cyrtophora* cf. *citricola. This Asian and Mediterranean species has been found to be somewhat more common in the UAE than originally thought. Previously it was found living in loose colonies of associated webs in coastal shrubs in Ras al-Khaimah, with a single individual in a shrub in the mountains overlooking the coast north of Dibba. It has since been found in a similar colony of at least 8 well-formed "basket" webs in the sheltered interior of a ghaf tree in plantations bordering urban Dibba (Fujairah) (Fig. 14a). It has also been identified in an old photo showing a larger aggregation of webs on the grounds of Fujairah National Diary Farm, spreading across dry rushes and into an adjacent Acacia tree at the edge of a pond (Fig. 14b). All known sites happen to be located within two kilometres of the coast.

The Dibba ghaf tree colony was observed in mid-October 2016. Females were resident in most webs and were typically perched upside down inder a pendant row of 2 to 4 egg cases. One female showed toasted marshmallow colouring, very different from the normal off-white with black markings (Fig. 14c). A tiny male was also found (Fig. 14d), perched on a small platform within a female's basket web.

Fig. 11 *Hasarius adansoni*: A male from the grounds of Emirates Towers. (BR)

Fig. 12a *Hyllus dotatus*: Dorsal view of a male from a coastal plantation in Fujairah. (BR)

Fig. 12b *Hyllus dotatus*: Oblique view of the spider shown in Fig. 12a. (BR)

Fig. 12c *Hyllus dotatus*: A female from a coastal plantation in Fujairah. Females of *H. dotatus* closely resemble those of *Plexippus paykulli*. (BR)

Fig. 13a A typical sheet web of cf. *Benoitia lepida* on the sandy periphery of Ain al-Faydhah, built in the shelter of a spreading *Zygophyllum* shrub. A pendant egg case can be seen at top centre. (GRF)

Fig. 13b cf. *Benoitia lepida*: A spider alert in its web at Ain al-Faydhah. These spiders were active in mid-afternoon, even in mid-September. (BR)

Fig. 14a *Cyrtophora* cf. *citricola*: Multiple basket webs (eight or more) in a ghaf tree in plantations on the outskirts of urban Dibba (Fujairah). (GRF)

Fig. 14b A large community of *Cyrtophora* cf. *citricola* webs in ghaf trees beside a pond at Fujairah National Dairy Farm in spring 2003. (GRF)

Fig. 14c *Cyrtophora* cf. *citricola*: An unusually colourful female from the community shown in Fig. 14a. (GRF)

Fig. 14d *Cyrtophora* cf. *citricola*: A tiny male found within the basket web of a female from the community shown in Fig. 14a. (GRF)

ERESIDAE

Stegodyphus* cf. *nathistmus. This species was originally recognised from wild sites in the Hajar Mountains but it appears to inhabit a broader range of environments. We have since found it, for example, in the top of a saltbush near the Fujairah coast (Fig. 15) and in palm fronds at a height of slightly more than two metres above the ground, in a stream beside plantations in Wadi Hayl. In no instance, however, have the shelters we have seen been as elaborate or conspicuous as the very first one which attracted our attention (see Feulner & Roobas (2015) at Figs. 18.1 and 18.2).

Fig. 15 *Stegodyphus* cf. *nathistmus*: A spider in its web in the top of a dry saltbush on the Fujairah coast. (BR)

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Five-striped Palm Squirrel, *Funambulus pennantii* (Wroughton, 1905) – a new addition to the UAE's exotic fauna

by Jacky Judas and Peter Hellyer

In recent decades, continuing studies of the faunal biodiversity of the United Arab Emirates have not only identified for the first time many species that occur naturally, including, for insects and other arthropods in particular, numerous species which are new to science, but also many species which have escaped or have been deliberately introduced and have established self-sustaining feral populations. Many of these exotic species are birds. By June 2016, according to the Emirates Bird Records Committee, a total of 16 bird species were included in category C of the UAE checklist, indicating self-sustaining feral populations. A number of other species have bred but have failed to establish self-sustaining populations (Category E).
http://www.uaebirding.com/uaechecklist.html
(accessed 5th October 2016)

There are far fewer mammals and amongst these are well-established species, such as House Mouse (*Mus musculus)*, Black Rat (*Rattus norvegicus)*, and Brown Rat (*Rattus rattus)* which have probably been present for hundreds of years or more. *R. rattus* is known to have been present in the Middle East for at least 2,000 years. Feral populations of goats (*Capra aegagrus hircus*) have also become widely established in the Hajar Mountains as well as donkeys (*Equus africanus asinus*). Additionally, the Rock Hyrax (*Procavia capensis*), released during the 1990s, has maintained a small population up until today around an artificial water source on Jebel Hafit, Al Ain – Abu Dhabi Emirate (Drew C. & L. 2004), and is also a common introduced species on Sir Bani Yas island.

The Indian grey mongoose *(Herpestes edwardsii)* was recorded in the northern emirates in the 1980s and two animals that may have been this species were seen in Abu Dhabi in 1985 and 1988, (Hellyer & Aspinall: p. 313), although the lack of recent published records may indicate that the species has failed to establish a viable self-sustaining population.

Over the last seven years, since 2009, widespread and increasingly frequent sightings of Palm Squirrel (*Funambulus sp.*) have been reported. Initial reports suggested that the species present was the Indian Palm Squirrel (Wilson 2009, Anonymous 2011, Feulner 2013), also called Three-Striped Palm Squirrel (*Funambulus palmarum* - Linnaeus, 1766). However, a thorough review of all photographic material available suggests that the palm squirrel present in the UAE is most probably the Five-Striped Palm Squirrel (*Funambulus pennantii* – Wroughton, 1905). This identification has been confirmed by Dr. P.O. Nameer, a mammal specialist from the Centre of Wildlife Studies, Kerala Agricultural University- India, and the IUCN Red List status reviewer for Palm Squirrels.

As with the Indian Palm-Squirrel, the Five-Striped Palm Squirrel has 3 dorsal longitudinal yellow stripes across his dark brownish back, but differs from the later by also having a more or less distinct longitudinal yellow stripe bordering the dark mantle on the flanks (see pictures 1 to 3). All pictures of Palm Squirrel photographed in the UAE, including older records, made available to us on which the flanks of the

animals are clearly visible allow the identification of the Five-Striped Palm Squirrel. There is thus far no confirmed evidence of the presence of the Three-Striped Palm Squirrel.

The 42 records collected to date (Table 1) of this mammal, spread throughout the country, suggest that the Five-striped Palm Squirrel (*Funambulus pennantii*) can now be added to the UAE's exotic, self-sustaining, mammal fauna.

No squirrels are native to the UAE, although a number of individuals of the Persian squirrel (*Sciurus anomalus*) survived from at least 1999-2003 in parks and gardens in Abu Dhabi, having originally been introduced for the pet trade (Aspinall *et al.* 2005). In the absence of any subsequent records, this species may not have succeeded in establishing a self-sustaining population.

The first published record of Palm squirrel for the UAE was posted on the citizen science and online social network iNaturalist on 30 January 2011 by Johnny Wilson, a visiting American naturalist, who related the sighting of a squirrel, which he photographed, in Al Hamraniyah farms on 17 August 2009 (http://www.inaturalist.org/observations/10691).

A second record appeared in the April 2011 edition of the newsletter of the Dubai Natural History Group, **The Gazelle**, one having been photographed near a Fujairah housing complex (White Village) by local resident Joseph Viker (Anonymous 2011). Re-examinations of pictures of these first two records support their identification as Five-striped Squirrel, rather than Indian Palm Squirrel, as previously reported. Several other records from Fujairah are known. For around nine months from February 2014, a family of three was seen in the vicinity of the Fujairah Maternity Hospital by Minie van der Weg, while on 31st October 2015, one was seen by PH and Suzanne Hellyer in the gardens of the Fujairah Hilton Hotel. (Hellyer 2015).Two more were seen at the Fujairah Hilton, apparently breeding in a palm tree, on 30th April 2016 (Peter Arras, *pers. comm.)* and another on 7th October 2016 (Suzanne Hellyer, *pers. comm.*)

Other sightings in the Fujairah area, by JJ, include several records in May 2013 in palm plantations and inland farms of Rugheilat, a southern suburb of Fujairah City. Other records by JJ include animals on farms in the Kalba district (Emirate of Sharjah) in August-September 2013, and in Ayn Al Madhab Park

Table 1: Distribution of records of the Five-Stripped Palm Squirrel (*Funambulus pennantii*) per year and Emirate

	Year of records						
Emirate	**2009**	**2011**	**2013**	**2014**	**2015**	**2016**	**Total per Emirate**
Abu Dhabi			1			2	3
Ajman					1		1
Dubai			2	2	2	1	7
Fujairah		1	2	2	3	6	14
Ra's al-Khaimah	1			1	1	5	8
Sharjah			1	1	2	6	10
Total per year	**1**	**1**	**6**	**6**	**9**	**20**	**43**

– Fujairah on 23rd November 2013. Ahmed Al Ali recorded the calls of a squirrel he saw in Kalba on 29th December 2015.

Other sightings by JJ on the UAE's East Coast at Wamm, an area of Dibba, include 1 - 2 individuals, 4 April 2014, 04 September 2015 and 12 March 2016. One was seen on 8th April 2016 in a goat farm in the Wamm area during a birdwatching visit (Simon Lloyd *pers. comm.*) with another being seen the same month by Steve Taylor (*pers. comm.*).

At least two animals have also been recorded in Dibba-Bayah, the part of Dibba that belongs to the Sultanate of Oman, in the gardens of a dive centre, in September 2016 (Chris Chellapermal, *pers. comm.* 24th September 2016).

There are several published records from Dubai, the first of which was a 'pair' seen in Jumeirah 3, Dubai, by resident Michel de Martigny in his garden in early 2013, this being reported in the June 2013 issue of **The Gazelle** (Feulner 2013, Hellyer 2015) .

Elsewhere in Dubai, Mike Barth photographed one individual in Dubai's Safa park on 29 January 2014 (UAEBirding forum), where JJ also observed the species on 13 March 2014, Mark Smiles recorded "1-2 pairs" there in 2015, (*pers. comm.*), and Huw Roberts also recorded them in early 2016 (*pers. comm.).*

In Nad Al Sheba 2, Howard Heaton reported in May 2016 that squirrels have been in his garden "for the past three years", i.e. since 2014. "Last year 2015, we counted at least five and believe they had bred… This year, I've counted three but there could be more… " (*pers. comm.*)

Palm squirrels have also been seen during 2015/2016 in the palm garden on The Palm Jumeirah (Justin Ede, Tommy Pedersen, *pers. comm.*).

In Abu Dhabi, a single animal was seen on the E16, south of Al Samha and around 2 km, from the Tulip Inn in 2013, the first on record for Abu Dhabi Emirate so far (Josh Smithson, *pers. comm*). 4 were seen on 29th April 2016 in the wooded garden by the Emirates Heritage Club compound on Abu Dhabi's Marina Mall breakwater (Oscar Campbell, *pers. comm.*).

Palm squirrels have also been reported from the farms in the Hamraniyyah area of inland Ra's al-Khaimah, 2 by Greg Askew and Alec Napier on 3rd December 2015, by JJ on several occasions (9 January, 19 February and 8 April 2016) and, also by Mark Smiles in January 2016, (*pers. comm.*).

In Sharjah, they have been described as "very common" in Sharjah National Park (Steve Taylor, *pers. comm.*), where Priscilla Van Handel estimated more than 50 individuals on 13 July 2016 (see pictures), and observed them eating dates and picnic left-over on the ground. They have also been seen in early 2016 near Sharjah University (John Johnston, *pers. comm.*)

Ahmed Al Ali, of the Sharjah Environment and Protected Areas Authority, EPAA, has reported that they are present in the Dhaid area and Kaati Park, Al Hamriyah, Ajman (*pers. comm.*).

With the species now having been recorded from, at least, Fujairah, Kalba, Dibba, several areas in Dubai, Samha, Abu Dhabi city, Sharjah, Dhaid, Ajman and Hamraniyyah, including 'pairs' and young, it is evident that a widespread and probably self-sustaining population has already been established.

The number and distribution of 4 sub-species (*F.p. pennantii*, *F.p. argentescens*, *F.p. chhattisgarhi* and *F.p gangutrianus*) are still debated, and no studies have yet been undertaken to determine which one is present in UAE.

The Northern Palm Squirrel is native to India, Nepal, Bangladesh, Pakistan and Iran, but was introduced in Andaman and Nicobar Islands, New Caledonia, Papua New Guinea, Fiji, Samoa, Tonga, Nauru, Vanuatu and Australia, where it has since become a minor pest.

The closely-related species, the Indian palm squirrel, *F. palmarum*, is found naturally in southern India and Sri Lanka and was introduced in the late 19th century in Reunion, Mayotte, Comoro, Madagascar, Mauritius, Seychelles and Australia, where it has become a minor pest.

Studies in Australia, where both species have successfully naturalised in Perth, although the Indian Palm Squirrel has been eradicated in Sydney, have suggested that these species have the potential to become a serious pest. A risk assessment by the Government of Queensland (Anonymous 2016) has concluded that *F. palmarum* and *F. pennantii* are serious pests of fruit crops in India and also eat birds' eggs.

The species can only be kept in Queensland as pets under license, in accordance with the Nature Conservation Act 1992, and are required to be made infertile.
https://www.business.qld.gov.au/industry/agriculture/species/declared-pests/animals/indian-palm-squirrel

Australia's National Vertebrate Pests Committee classes palm squirrels as "an extreme threat", while the Non-Indigenous Animals Act defines them as a species of "high pest potential."
http://www.smh.com.au/nsw/squirrels-on-sale-trendy-pets-or-just-a-little-nuts-20100731-110mj.html

Although the Northern Palm Squirrel clearly arrived in the United Arab Emirates as pets, subsequently either escaping or being deliberately released, they appear now to have become naturalised residents. In their home countries, this species is known to be very adaptable, using a large range of habitats from dry deciduous subtropical forest and scrublands to plantations, rural and urban areas.

Cute they may be, but they clearly have the potential to become pests here, as they have done in Australia. Given the apparent recent and fast spread of the species in the UAE, perhaps as a result of a succession of escapes or releases, and without clear regulations on their import, it is likely that the population will continue to grow.

Population monitoring and mapping of future sightings should be encouraged, as well as the study of their local ecology (diet, habitat preferences…) and population dynamic (breeding success and mortality, predation, competition with native species). The assessment of population status should be conducted in coordination with neighbouring countries (Oman in particular), since the species can easily move from one country to the other, as may be suggested from the single sighting in the Omani part of Dibba.

All future sightings can be communicated to Jacky Judas (JJ) who is currently compiling a database of UAE mammal records, and would be pleased to receive any other records of native or exotic mammal fauna.

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New Flowering Plant Species Records for the United Arab Emirates

by Mohammad Shahid and N.K. Rao

Abstract

Six wild plant species not previously documented in the United Arab Emirates are presented. *Iphiona mucronata* (Asteraceae) was observed at Dibba, on the UAE East Coast. *Arenaria deflexa*, which belongs to the family Caryophyllaceae was found in Wadi Ghalilah (Ra's al-Khaimah). *Chenopodium carinatum* (Chenopodiaceae) was found in Al Ain. One of the Fabaceae species, *Medicago lupulina*,was identified at the International Centre for Biosaline Agriculture (ICBA) in Dubai. The Cyperaceae species *Cyperus longus* was spotted at Ruwayya, Dubai, while *Eleusine indica,* a species of the Poaceae family, was also found in Wadi Ghalilah. Five of the reported species are native, while *C. carinatum* has been introduced.

Fig. 1 An *Arenaria deflexa* flower

Introduction

The United Arab Emirates (UAE) has a diverse wild flora, inhabiting a range of different habitats. Work by many researchers had described a total of around 810 by the end of 2015 (Shahid and Rao, 2015). In 2016, researchers have reported more previously undocumented wild species from the UAE (El-Keblawy *et al.,* 2016; Mahmoud, *et al.,* 2016; Shahid and Rao, 2016) bringing the number of described plant taxa from the UAE to about 820.

That part of the Hajar mountain which lies in the UAE is rich in wild plant species (Western, 1989; Jongbloed, 2013), but, due to the nature of the terrain, it is difficult to explore thoroughly, particularly at higher altitudes. Further undocumented species may be present here, as well as in other parts of the country. Continued research to identify introduced species is also of importance.

The Plant Genetics Resources laboratory of International Centre for Biosaline Agriculture (ICBA) has been working to document the wild flora of the UAE since 2012 with over 20 previously unrecorded species being identified (Shahid, 2014; Shahid and Rao, 2014; Shahid and Rao, 2014a; Shahid and Rao, 2015; Shahid and Rao, 2015a; Shahid and Rao, 2015b; Shahid and Rao, 2016).

Materials and Methods

During 2014-16, many botanical expeditions were undertaken in various parts of the UAE to document the local wild flora. A Garmin GPS 72H was used to record the geographical co-ordinates of the plants while data on the habitats and plant populations were also recorded. For species identification, pertinent literature (Chaudhary, 1989; Chaudhary, 1999; Chaudhary, 2000; Chaudhary, 2001; Chaudhary, 2001a) was used.

Results and Discussions

1. *Arenaria deflexa Decne,* Ann. Sci. Nat., Bot. II, 3: 277. 1834 (Figs. 1, 2, 3)

A perennial herb; stems tufted, hairy, slight, prostrate to semi-erect, 15-30 cm long, form mats

Fig. 2 *Arenaria deflexa* plants growing in a farm at Wadi Ghalilah, Ra's al-Khaimah

Fig. 3 An *Arenaria deflexa* plant

frequently. Leaves ovate-elliptic, sessile or 1-3 mm petiole, glandular-hirsute, acute, 0.3-1.5 x 0.2-.6 cm. Flowers in lax dichasial cymes, pedicel 2-7 mm long. Bracts petite, linear lanceolate. Sepals 2-5 mm, narrowly lanceolate, acuminate, scarious-margined. Petals white, 3-5 mm long, entire or retuse, oblong-linear. Capsules 3-4 mm, conical or flask-shaped. Seeds 0.5-0.7 mm long, covered with tubercles. Flowering February to May.

The natural range of *Arenaria deflexa* is the eastern Mediterranean countries, including Greece, Turkey, Lebanon, Syria, Israel, Jordan and Egypt. It has also been reported from Saudi Arabia (Chaudhary, 1999).

From the UAE, the species was recorded for the first time in Wadi Ghalilah (25°58.919 N, 056°08.658 E), a mountainous area in the emirate of Ra's al-Khaimah, where it was found at three different locations. This Caryophyllaceae has also been reported from Saudi Arabia. *A. serpyllifolia* is another species of the genus *Arenaria* found in the UAE.

2. ***Chenopodium carinatum*** **R.Br**., Prodr. Fl. Nov. Holl. 407. 1810 (Figs. 4, 5)

Annual herb. Stems prostrate to erect, much branched near base, aromatic, pubescent, 20-50 cm, glandular, glands sessile or stalked. Leaves alternate, ovate to elliptic, 0.25-3 x 0.2-2 cm, somewhat smaller in inflorescence, slightly lobbed to coarsely serrated, glandular on both surfaces, upper surface pubescent, hairs along veins on lower surface. Inflorescence few to many flowered, lateral cymes or glomerules, 1.0-2.5 mm diam., bracts leaf like, 3-5 mm, elliptic, apex blunt, margins crenate-dentate; perianth 5, greenish, erect, hirsute, glandular, 0.5-0.75 x 0.2.0.3 mm, sessile or sub-sessile; stamens 0-1, stigma 2. Fruit ovoid, somewhat ridged. Seeds reddish brown to black, often keeled, ovoid, smooth surface, glossy, 0.5-7 x 0.5-6 mm. Flowering March-May.

Chenopodium carinatum is native to Australia, elsewhere it has been introduced as a weed. In the

Fig. 4 *Chenopodium carinatum* plants on a roadside in Al Ain

Fig. 5 Leaves and inflorescences of *Chenopodium carinatum*

Arabian Peninsula, it has also been recorded in Saudi Arabia (Chaudhary, 1999).

In the UAE, the species was noted by the authors at a single place in the city of Al Ain (24°13.096 N, 055°45.551E). It was found on an irrigated sandy soil along a roadside, where around 5 plants were growing close to one another. Apart from *C. carinatum, C. album* and *C. Murale* are other members of the genus *Chenopodium* to have have been recorded from the UAE.

3. ***Cyperus longus* L.**, Sp. Pl. 41. 1753 (Figs. 6, 7)

Perennial sedge, erect, 60-100 cm tall. Rhizome ligneous having short stolons. Culms 50-100 cm long, flat, triangular. Leaves shorter than culms, lamina smooth, 35-45 x 0.5-0.7 cm, keeled. Inflorescence relatively lax composite anthelidium; bracts flat, leaf like, 3-6, different in length, longer surpassing the inflorescence. Primary pedunculate rays many, dissimilar, all with cluster of 5-15 spikelets at their tips. Spikelets slender, with several flowers, 10-20 mm long, 1-1.5 mm wide. Glumes 2-3 mm long, boat shaped, obtuse, pale brown with wide yellow margin, keeled. Stamens 3; stigma 3. Fruit trigonal, 0.8-1 mm long, oblong.

Cyperus longus is native to the Old World where it is found in various parts of Africa, Asia and Europe. In Arabia, it has been documented from Oman (Ghazanfar, 1992), Saudi Arabia (Chaudhary, 2001a) and Yemen (1997).

The species was observed at Ruwayya (25°05.346 N, 055°23.412 E), an area of Dubai. Around 15 plants were growing in two tree pits that were regularly provided with irrigation water. Six taxa of the genus *Cyperus* have already been documented from the UAE, *C. longus* being the seventh.

4. ***Eleusine indica* L.** Sp. Pl. 41. 1753 (Figs. 8, 9, 10)

Annual, caespitose, much branched at base, tufted, 25-70 cm tall, culms ascending or prostrate, slender, smooth, green, glabrous and rather flattened, mostly covered by sheaths. Most leaves at the base of culms; leaf sheaths loosely cover culms, relatively flattened, largely hairless, light to medium green, veined; leaf blades 20-25 cm long, 5-8 mm wide, medium to dark green, mostly glabrous, margins with infrequent curved hairs, keeled. Ligules white, membranous. Inflorescence comprised of 1-10 racemes, which are digital, 3-15 cm long, 2.5-3.5 mm wide; rachis depressed, wingless. Spikelets solitary, sessile, compressed, elliptic, 3-5 mm long; each spikelet has 3-9 fertile florets. Glumes persistent; higher glumes elliptic, 1.5-3.0 x .5-1.0 mm; lower glumes lanceolate, 1-2.5 x 0.5-0.8 mm, veined, keeled, keel with wing. Lemma lanceolate, somewhat acute, 2-3.5 mm long, 3-veined, apex acute. Palea 2-veined. Pericarp persistent, loose, membranous, surrounding the seeds. Fruits trigonal, ellipsoid, 1-1.5 mm long, black, covered by encircled florets. Flowering February to May.

The natural distribution of *Eleusine indica* includes much of Africa and Asia as well as parts of southern

Fig. 6 *Cyperus longus* plants in a tree pit at Ruwayya, Dubai

Fig. 7 Inflorescences of *Cyperus longus*

Fig. 8 *Eleusine indica* plants in a fenced fallow farm at Wadi Ghalilah, Ra's al-Khaimah

Fig. 9 Young *Eleusine indica* plants

Fig. 10 Inflorescence of *Eleusine indica*

Fig. 11 An *Iphiona mucronata* plant in gravel soil at Dibba, Fujairah

Europe. It has been introduced in North America and elsewhere. In the Arabian Peninsula, it has been documented from Oman (Ghazanfar, 1992, Qatar (Flora of Qatar online), Saudi Arabia (Chaudhary, 1989) and Yemen (Wood, 1997).

In the UAE, the species was found in two fenced and fallow farms in Wadi Ghalilah (25°58.631 N, 056°09.061 E), Ra's al-Khaimah. More than 50 plants of the grass were present. Two other species (*E. compressa* and *E. coracana*) of the genus *Eleusine* have been previously documented in the country (Jongbloed 2003; Karim and Fawzi, 2007).

5. ***Iphiona mucronata* (Forssk.) Asch. & Schweinf.**, Mém. Inst. Egypt. 2: 86. 1887 (Figs. 11, 12)

An annual herb. Stems sulcate, intricately branched, rigid, 25-50 cm long, glabrous, young shoots glandular, glands sessile. Leaves subulate, stiff, sessile, with spines, entire or with 1-5 spinescent lobes on both sides in basal half. Capitulas light yellow, solitary, with long peduncles, terminal, arranged in loose cymes. Involucral conical or cylindrical. Involucral bracts mucronate, hairless, obtuse, narrowly thin-margined. Fruit (achene) ridged, heavily pubescent, 2-2.5 mm long, with many pappi of various sizes, usually twice the length of achene. Flowering February to April.

Iphiona mucronata has been reported from areas in and around the Sinai Peninsula (Egypt) including Palestine, Israel, Jordan and north-western Saudi Arabia.

The species was observed growing on gravel soil at Dibba (25°35.801 N, 056°15.075 E), on the East Coast of the UAE, far from what is considered to be its natural range.

Fig. 12 *Iphiona mucronata* flower

Fig. 13 A *Medicago lupulina* plant

6. ***Medicago lupulina* L.** Sp. Pl. 41. 1753 (Figs. 13, 14, 15)

Annual to short lived perennial herb. Stems ascending to prostrate, 10-25 cm long, hirsute. Leaves alternate, composed (trifoliate), petiolate; petiole 2-2.5 cm long; stipules ovate-lanceolate, entire or dentate,

Fig. 14 Flowers of *Medicago lupulina*

Fig. 15 Pods and inflorescences of Medicago lupulina

Table-1. Information on the six previously undocumented plant species found in different parts of the United Arab Emirates

S.N.	Species	Family	Place	Emirate	GPS Coordinates	
					N	E
1	*Arenaria deflexa* Decne	Caryophyllaceae	Wadi Ghalilah	Ra's al-Khaimah	25°58.919	056°08.658
2	*Chenopodium carinatum*	Chenopodiaceae	Al Ain	Abu Dhabi	24°13.096	055°45.551
3	*Cyperus longus*	Cyperaceae	Ruwayya	Dubai	25°05.346	055°23.412
4	*Eleusine indica*	Graminae	Wadi Ghalilah	Ra's al-Khaimah	25°58.631	056°09.061
5	*Iphiona mucronata*	Asteraceae	Dibba	Fujairah	25°35.801	056°15.075
6	*Medicago lupulina*	Leguminosae	ICBA	Dubai	25°05.798	055°23.413

pointed. Leaflets obovate to elliptic, 3-18 mm long, 3-9 mm wide, pubescent, upper half serrate, apiculate. Inflorescence axillary, racemes pedunculate, peduncle 2-4 cm long, compact, 10-50 flowers. Bracts 0.3-0.5 mm long. Pedicels 0.5-1 mm long. Calyx hirsute, 1-1.5 mm, serrate, teeth equal or longer than tube. Corolla yellow, 2-4 mm long. Pods kidney shaped, reticulate, hairy to glabrous, black at maturity, 2-3 mm long, 1-seeded. Seeds brown or yellow, 1-2 mm long. Flowering February to April.

The range of *Medicago lupulina* covers Europe, North Africa and West and South Asia. It has been recorded from Saudi Arabia (Chaudhary, 2001) and Yemen (Wood, 1997).

The species was located at the International Centre for Biosaline Agriculture, ICBA (25°05.798 N, 055°23.413 E) Dubai, where about five plants were growing on sandy soil in an irrigated field. Three other *Medicago* species have already been described from different parts of the country (Jongbloed, 2003; Karim and Fawzi, 2007), making *M. lupulina* the fourth species of the genus to be found in the UAE.

Conclusions

Four of the six newly-recorded plant species (Table-1) were found only at a single location, making them rare in the UAE. With the exception of *Chenopodium carinatum,* all the other reported taxa may occur naturally, while *C. carinatum* may have been accidentally introduced.

Arenaria deflexa and *Eleusine indica* were both observed in Wadi Ghalilah, Ra's al-Khaimah. Both were growing inside farms surrounded by fences, thus protected by grazing from goats (*Capra hircus*), which were common outside the fences. *A. deflexa* was found at 3 various three farms, while *E. indica* was seen at two different locations. The two species and

other palatable wild flora were not seen growing outside the fenced farms probably due to the presence of goats, where another species, *Tephrosia apollinea,* was growing extensively. *T. apollinea* is toxic to goats (Suliman *et al.,* 1982) and other grazing animals..

The authors noted more than 30 wild plant species in the enclosed farms, which were not present around or near the farmhouses, outside the fences. Another previously unreported species, *Sida spinose*, had earlier been recorded within the fenced areas (Shahid and Rao, 2016).

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Growing knowledge about the floral diversity of United Arab Emirates: new additions and conservation through seed banking

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Abstract

The Arabian Gulf region contains a rich, unique and diverse flora. Previous field surveys in the region have highlighted the importance of documentation and conservation of biodiversity in such arid environments. In this article, we briefly review botanical surveys in the United Arab Emirates (UAE), and the efforts made for genetic resource conservation through seed banking. Despite its aridity, the UAE has a relatively rich flora, especially in regions that retain some moisture during the summer months, including some microhabitats of mountainous regions, wadis and silt pans in front of dams. Recent collecting efforts and field surveys by the authors and other researchers have added around 30 species to the UAE flora, bringing the total known species to around 830. This is the direct result of an increase in the number of researchers and organisations interested in botanical exploration and plant taxonomy in the country. However, more efforts are needed to explore and document the floral wealth of the country. With regard to plant genetic resources conservation, seed banking has become an essential tool worldwide. The Sharjah Seed Bank and Herbarium (SSBH) of the Sharjah Research Academy (SRA) was established in 2009 to explore, collect, and conserve the plant genetic resources of the country. SSBH was established with technical support from the Royal Botanic Gardens, Kew, UK. Its major aim is to establish seed banking of wild plant species in the UAE, for long-term *ex situ* conservation of native wild taxa and to make available information for seed materials that could be used for basic or applied research. So far, about 4000 herbarium and 1500 seed collections representing over 50 percent of the UAE's plants are preserved in SSBH under the standard conditions set by Kew. There remains a need for further research and for the building a broader knowledge base among plant scientists.

Keywords: *Ex situ* conservation; Floral diversity; New plant records; Sharjah Seed Bank and Herbarium, United Arab Emirates

Introduction

It is widely acknowledged that the establishment of natural history collections is central to the study of species diversity, and may be its most enduring legacy (Blackmore 1996; Wheeler *et al.* 2012). An increase in biodiversity exploration is necessary if we are to document species and their distribution before they become extinct (Webb *et al.* 2010). Such field studies also promote conservation by increasing awareness of populations and distribution, particularly if researchers from various backgrounds engage together in complementary ways (Novacek 2008). A promotion of public awareness about the significance of plant diversity and its conservation is also a responsibility for professional scientists, to increase knowledge of the environment and the need to protect it.

The United Arab Emirates (UAE) is situated in the south-east of the Arabian Peninsula, with the majority of its landmass being comprised of sand desert with massive dunes and scattered oases, bordered by the Hajar Mountains in the north-east. The climate is mostly arid to hyper-arid with low and irregular rainfall in most areas (Boer 1997), although more rainfall occurs in mountainous areas. These represent only around 10% of its total area, but are known to contain more than 50 per cent of the plant species so far identified (Al-Ansari and El-Keblawy 2003). Many of the UAE plant species have evolved to survive harsh environmental stresses, such as salinity and high temperatures that can reach around 50°C during summer (Gairola *et al.* 2013). These species show specific physiological, behavioural and morphological adaptations — to survive in the harsh environmental conditions (Tourenq and Launay 2008). At present, around 830 species are known to be present, including those in the mountains. Further species can be expected to be identified. Over the last five years, the authors and other researchers have added about 30 new records to the country's flora, around four per cent more than those recorded in Jongbloed (2003) and Karim and Fawzi (2007). This reflects an apparent increase in the number of surveys being undertaken and in the publication of results. Such studies, at least in part, are supported by the government with a view to providing information that can help decision-making on biodiversity issues. Government has also

supported long-term projects such as the development of the seed bank and plant genetic resource centre.

The Sharjah Seed Bank and Herbarium, SSBH, currently houses around 1500 seed accessions, from around 430 taxa, these being banked in accordance with international standards and being maintained in freezers kept at a temperature of – 18° C. Initially, a particular emphasis was placed on the native plants of the Emirate of Sharjah although the scope has now expanded to cover the whole of the United Arab Emirates.

Some of the earliest collections of SSBH were split into two seed lots, with a backup sample of each stored at the Millennium Seed Bank (MSB), UK. Beside collecting and banking seeds of the flora of the UAE, the SSBH also aims to build up comprehensive herbarium collections for the region. Currently, the herbarium at SSBH houses more than 4000 specimens of vascular plants, primarily from the UAE. New specimens are continually added as a result of fieldwork and the collection now serves as a substantial resource for scientific research, including floristic and systematic studies.

Botanical exploration and new additions to UAE flora

The pioneer investigators and researchers on the UAE's flora were Jongbloed (1987), Western (1989), Karim (1995), Böer and Eschmann-Grupe (1996), Roshier *et al.* (1996), Feulner (1997), Böer and Chowdary (1999), Böer and Al-Ansari (1999), and Jongbloed *et al.* (2000). Jongbloed (2003) and Karim and Fawzi (2007) produced comprehensive guide books that generated increased interest and facilitated further studies. Feulner (2011) published an annotated checklist of the flora of the Ru'us al-Jibal, adding at least 17 species not previously recorded in Eastern Arabia, and Feulner (2014) highlighted a number of rare species found in the Olive Highlands, south west of Fujairah, including a new UAE/Oman endemic. Brown and Sakkir (2004) published the vascular plants of Abu Dhabi Emirate. Plants of the mountainous Wadi Helo area were described by El-Keblawy (2011) and El-Keblawy *et al.* (2016). Important contributions to the flora of the UAE were made by a series of joint botanical collecting trips involving the staff of Kew Herbarium and SSBH which led to the addition of five new records to the flora of the UAE (Heller and El-Keblawy 2013). Recently, Sakkir and Brown (2014) studied the vascular flora of Jebel Hafit and provided some new records for its flora.

The earliest UAE floristic survey by Western (1989) described about 480 species. Jongbloed (2003) subsequently described around 680 species. Karim and Fawzi (2007) noted about 600 species, including about 70 taxa not previously recorded, but some previously described taxa, especially mountain species, were not included in their books. Feulner (2011) reported on the distinctive flora of the Ru'us al-Jibal (the mountains of the Musandam peninsula) and brought the list of plant taxa up to 790, making significant additions to the botanical knowledge of the country. In addition, in a survey of Wadi Helo, El-Keblawy (2011) recorded around 230 species and suggested that further work could add more species to the flora of the country.

Building on the earlier studies mentioned above, botanical studies in the UAE are increasing. Floral surveys by various researchers (e.g., Feulner 2011; Heller and El-Keblawy 2013; Shahid 2014; Shahid and Rao 2014a, 2014b, 2015; Gairola *et al.* 2015; Mahmoud *et al.* 2015a, 2015b; Mahmoud *et al.* 2016; Shahid and Rao 2016) identified the presence of some 30 plant species new to the UAE (Table 1). Of these, most are from anthropogenic environments, such as farms, roadsides and lawns, and are most likely to have been introduced, deliberately or accidentally. Only four species, from mountain areas, are likely to be native.

The number of plant species known from the UAE is likely to continue to grow, as a result of further field work and no estimation of the total number of vascular species present is possible. Continued publication of new discoveries represents an important contribution to a baseline of the taxonomy, distribution, and status of existing native species of the country.

The biodiversity of the UAE and its various environments is much greater than had been generally been recognised, until the studies of recent years. These environments overlap national borders with Oman. For example, the Ru'us al-Jibal (the mountains of the Musandam peninsula) is shared between Oman and the UAE. This biologically diverse region has 75 species that are not known elsewhere in the Arabian Peninsula (Feulner 2011). Five species locally endemic to the UAE and Oman are found in Ru'us Al Jibal, *Desmidorchis arabica, Echinops erinaceus, Pulicaria edmondsonii, Pteropyrum scoparium* and *Stipa mandavillei* (Feulner 2011). Collaboration at a regional level, both for investigation and conservation purposes, could contribute to identifying, mapping and conserving of the regional floral diversity.

The main threats to biodiversity in the Arab Gulf region generally, are habitat destruction and fragmentation, while the emergent impact of climate change may post risk to species (El-Keblawy 2014). Many of the natural habitats in the Arabian Gulf region are threatened both naturally and anthropologically (Tourenq and Launay 2008). For example, introduction of the alien invasive *Prosopis juliflora* for the purpose of afforestation has resulted in the reduction of native flora in some areas of the region (El-Keblawy and Al-Rawai 2007; El-Keblawy and Abdel-Fatah 2013). Further studies may identify previously-unrecorded species, particularly in mountain areas, which would assist in the assessment of the genetic resources in the region. The establishment of germplasm banks can assist in conservation of native plant diversity of the entire region. In addition, recording and monitoring

Table 1. Recent additions to the flora of UAE

Family/Species	Locality	Habitat	Reference
Amaranthaceae			
Alternanthera sessilis	Dubai	Damp area adjacent to buildings	Shahid and Rao 2015
Amaranthus lividus	Dubai	Irrigated lawn	Shahid and Rao 2015
Asteraceae			
Bidens pilosa	Wadi Al Bih, RAK	Sandy, Farm	Mahmoud *et al.* 2015a
Gamochaeta pensylvanica	Dubai- Deira	Roadside, Lawn	Shahid 2014
Parthenium hysterophorus	Hamriyah coast	Sandy area, small garden	Mahmoud *et al.* 2015a
Verbesina encelioides	Umm Urge area, Khor fakan	Sandy roadside	Shahid 2014
Boraginaceae			
Echiochilon callianthum	Wadi Helo	Rocky hillside and Wadi bed	Heller and El-Keblawy 2013
Diplotaxis erucoides	Al Ain, Al Hayer	Roadside	Shahid and Rao 2015
Caryophyllaceae			
Silene arabica	RAK	Roadside	Shahid and Rao 2014a
Vaccaria hispanica	Ajman	Sandy roadside	Shahid and Rao 2014a
Commelinaceae			
Commelina benghalensis	Dubai	Roadside	Shahid and Rao 2015
Cyperaceae			
Cyperus eremicus	RAK	Close to the Arabian Gulf shoreline	Shahid and Rao 2015
Fabaceae			
Senna occidentalis	Al Ain	Wadi bed	Mahmoud *et al.* 2016
Sesbania bispinosa	Al Ain, Wadi Al Ain	Wadi bed	Mahmoud *et al.* 2015b
Trifolium repens	Dubai, Emirate highway	Sandy roadside	Mahmoud *et al.* 2015b
Gentianaceae			
Centaurium tenuiflorum	Sharjah-Kalba Road, Farm opposite Helo Shabia	Grass-dominated date palm plantation	Heller and El-Keblawy 2013
Gossypium herbaceum	Abu Dhabi	Roadside	Shahid and Rao 2016
Hibiscus trionum	Ajman	Roadside	Shahid and Rao 2016
Sida spinosa	RAK, Wadi Al Bih,	Farm	Shahid and Rao 2016
Sphaeralcea bonariensis	Dhaid Road, Sharjah	Sandy, beside farm	Gairola *et al.* 2015
Molluginaceae			
Glinus lotoides	RAK, Fujairah, Sharjah	Flooded Dam areas	Mahmoud *et al.* 2016
Nyctaginaceae			
Boerhavia erecta	Dhaid-Masafi road.	Gravel plain	Heller and El-Keblawy 2013
Plumbaginaceae			
Limonium stocksii	Kalba	Salt flat	Heller and El-Keblawy 2013
Poaceae			
Aristida mutabilis	Khor Kalba protected area	Gravel plain	Heller and El-Keblawy 2013
Bromus diandrus	Al Ain	Roadside	Shahid and Rao 2015
Lolium multiflorum	Al Ain, Al Hayer	Roadside	Shahid and Rao 2015
Rubiaceae			
Oldenlandia corymbosa	Dubai - Oud Metha	Grass fields, Lawn	Shahid and Rao 2014b
Scrophulariaceae			
Chaenorrhinum rubrifolium	Ru'us al-Jibal	Soil within stony scree	Feulner 2011
Kickxia elatine	Fujairah	Wadi Wurayah	Shahid and Rao 2015
Solanaceae			
Datura ferox	RAK	Mountainous area	Shahid and Rao 2014b

of exotic species can enable recognition of the need, if appropriate, for control of species which may be invasive.

UAE efforts in germplasm conservation through seed banking

The *ex situ* conservation of germplasm is increasingly acknowledged in conservation science and considered as an integral component of biodiversity conservation. Seed banking has become an essential restoration and conservation tool worldwide. In order to achieve the Target 8 of the Global Strategy for Plant Conservation (GSPC) by the end of 2020, countries should have at least 75% of their threatened species preserved in *ex situ* conditions with genetically representative collections, preferably in the country of origin. In addition, at least 20% of the threatened species should be recovered through restoration programmes. According to this target, priority should be given to critically endangered species. A recent report by Sharrock *et al.* (2014) showed that 29% of plant species on the IUCN Red List of Threatened Species are in *ex situ* collections, indicating that there is still a long way to reach the GSPC target. The GSPC has prompted the establishment of many new seedbanks across the globe (Cochrane *et al.* 2007; Godefroid and Vanderborght 2010). Currently, around 6 million accessions of plant genetic resources are conserved globally, of which about 90% are held in seed banks (Linington and Pritchard 2001). A recent report showed that about 420 institutions in 97 countries are involved in seed banking of wild plants, which are generally not included in agricultural seed banks. Among others, international networks like the Millennium Seed Bank partnership and the European Native Seed Conservation Network are involved in seed banking of threatened wild plants, making a major contribution towards increasing their representation in seed banks (Godefroid and Vanderborght 2010).

Seedbanks are a good way of conserving biodiversity, providing that seeds are of high quality and at maximum viability. Researchers typically monitor the flowering and seeding of plants in the field prior to collection. In addition, researchers at seed banks discuss seed banking issues such as target species for collection and creating duplicate collections; prioritising research needs for the species; germination testing and protocols; data management, and conducting research on target species. In general, for the majority of collections, there is little information available regarding germination behavior and seed viability in the seedbanks. Seeds can remain viable for extended periods if kept under optimal conditions of low temperatures and moisture.

As noted above, the UAE has genetically diverse plant resources but the natural ecosystems in the country are also susceptible to natural and anthropogenic activities, such as climate change, habitat fragmentation, prolonged and repeated drought, soil salinisation, overgrazing and development activities which threaten plants and alter their habitats (El-Keblawy 2016). As a result, the importance of *ex situ* conservation of target plants in seed banks as an essential back-up solution has been acknowledged by conservation biologists, policy makers and natural resources managers in the UAE (Gairola *et al.* 2013). The conservation of biological diversity is important for the whole Arabian Gulf region; the conservation of germplasm from UAE species is an important contribution to this process. Seed banking is an important strategy for doing this and the SSBH has pioneered seed banking of wild plant species in the UAE.

As a result of the personal commitment of H.H. Sheikh Dr. Sultan bin Mohammed Al Qasimi, UAE Supreme Council member and Ruler of Sharjah, to the conservation of natural habitats and plant genetic resources of the region, the SSBH was established in 2009 with technical support from the Royal Botanic Gardens Kew, UK. The SSBH currently contains about 1500 seed collections from all over the UAE, representing about 430 plant species, or a little over 50% of known UAE species. Approximately 15% of the collections are of locally rare species. This contributes to the efficient long term storage of UAE's native plant diversity and is particularly important at a time of rapid global change both for threatened species and, increasingly, for more common species that may be essential in restoration programmes. Moreover, the diverse plant germplasm that exists in the UAE is a possible repository of useful drought/salinity resistant and high temperature tolerance traits, which could potentially be utilised for various research purposes, including in crop improvement programmes. Currently, there is a focus on plant species to be found in mountainous areas of the country.

The top 10 families with a large number of seed accessions in SSBH include Poaceae, Fabaceae, Amaranthaceae, Asteraceae, Brassicaceae, Boraginaceae, Caryophyllaceae, Scrophulariaceae, Convolvulaceae, and Zygophyllaceae (Fig. 1). In addition, during fieldwork, some taxa have been identified as new records for the flora of the country. The collection strategy attempts to incorporate the genetic diversity of species throughout their geographic distribution. Seed samples of a species are collected randomly from different plants to ensure the maximum genetic representation of the population. All seeds are collected using internationally accepted standards. The main activities at seed banks are seed plant selection, planning the field trips for collection of mature seeds, seed cleaning, examination for any infestation, counting, germination testing, seed measurements, seed drying, packaging for long-term storage and database management for the incoming collections throughout the collecting season. Immediately after collection, seeds are cleaned and

divided into two groups. One group of seeds is germinated immediately (within a week), while seeds of the other group are dried at 15°C, 15% RH and stored at -18°C freezers for long-term. Typically, the types of collections in any seed bank are (i) Base collections – for long term conservation; (ii) Active collections – for medium term conservation, germination rate and viability evaluation, multiplication and distribution; and (iii) Duplicate collections (of base collections) – for long term conservation (which are housed for security at different locations from the corresponding base collections). The SSBH also aims to maintain such types of collections for its seeds.

In the routine research activities of SSBH, germination trials are conducted for all seeds, whether for short or long-term storage. The purpose is to determine the optimal germination conditions (temperature, light, pre-treatments etc.), germination rate, and percentage germination. Seed viability of stored seed samples of different species is determined by comparing the germination of fresh seeds of a species with samples of seeds stored in the freezer (i.e., at -18°C). Typically, germination level is determined at the time the seed is brought into the seed bank, after four or five years and ten years, thereby determining germination stability or decline in seed viability during storage. The seeds are germinated in incubators with alternating temperatures and light/dark regimes to mimic natural climatic conditions. The germination data of fresh seeds and after storage, is compared to determine the effect of storage on seed viability and longevity. For a seed collection, the seed quality can be assessed by dissection, germination tests and non-destructive X-ray analysis. All seeds eventually lose their vigour and finally their viability. How long seeds will remain viable in *ex situ* seed bank conditions varies by species and understanding differences in seed longevity is critical to the effective management of *ex situ* collections (Walters *et al.* 2005; Probert *et al.* 2009). Understanding such variability provides a scientific base for developing seed viability monitoring protocols for any seedbank. In addition, more research is needed to define the optimal conditions for maintaining seed viability and extend the longevity of the seeds under banking conditions. Some accessions can give low initial germination, but storage conditions and period may improve the germination level, especially for species that need after ripening process (i.e., to allow embryo growth during dry storage). If a decline in germination percentage of some accessions is observed, this is usually attributed to the physiological and genetic characteristics of species and pre-storage environment factors. In these circumstances, further studies from representative accessions would provide optimal conditions for their long-term storage and standardising the seedbank protocol. The germination test / viability status results can also indicate how often a conservation collection should be replenished or regenerated. It would be relatively easy to establish plants from stored seeds for re-introduction to the wild, but more extensive research and trials are needed to ensure successful re-introduction in the natural environment. As with all seedbanks worldwide, any seed stored in the SSBH can be made available for immediate multiplication, distribution for research and any associated germination monitoring.

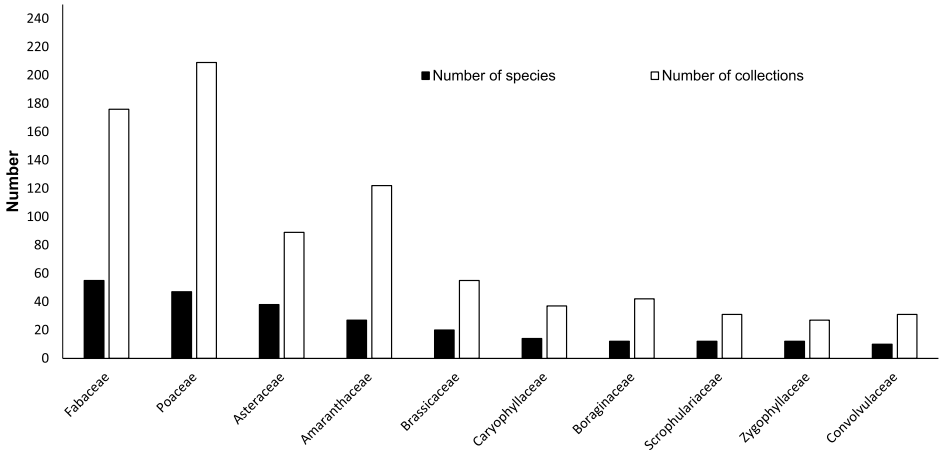

Fig. 1 Taxonomic coverage (as per families) of the SSBH seed collections.

SSBH Herbarium: a powerful resource for plant conservation efforts in UAE

Correctly identifying seed collections is essential if the seeds are to be utilised in any research or restoration programme. Consequently, it is essential to collect voucher materials such as herbarium specimens at the time of seed collection in order to

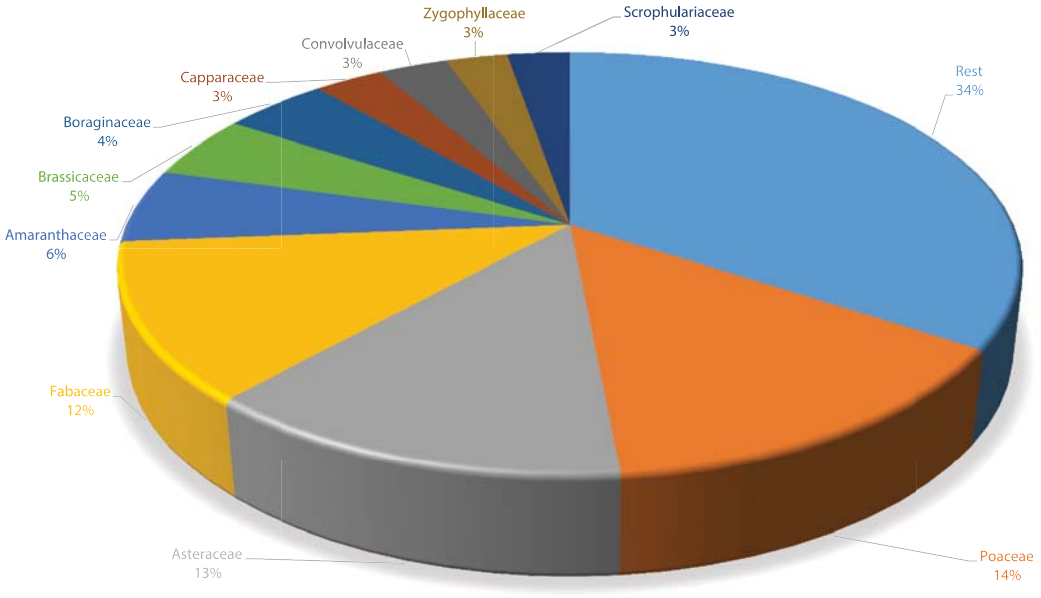

Fig. 2 Taxonomic coverage (as per families) of the SSBH Herbarium.

accurately identify seeds to a particular species and to verify collection names. Herbaria are storehouses of irreplaceable knowledge and key resources for plant classification and nomenclature and so contribute to cataloging biodiversity. For this reason, the SSBH aims to build up comprehensive herbarium collections for the flora of the UAE.

At SSBH, around 4000 herbarium collections have so far been made of around 410 species from the UAE. Each plant specimen is meticulously documented, identified by botanical experts and detailed information is recorded about the location where the plant was collected and its morphological characters. After field collection, plant specimens are dried in the plant press, mounted on acid-free paper, and accessioned into the collection. Some of these collections are also duplicated at the Kew Herbarium. The earliest specimen collections were mainly from the Northern Emirates, but at present the collection contains a wide representation of plants from the entire country. Some of these collections are of rare or poorly known species, including plant specimens of taxa newly recorded from the country. At present, the SSBH herbarium represents 69 families, as shown in Figure 2. The collection is growing continuously as a result of fieldwork. To manage our collections, we have selected BRAHMS (Botanical Research and Herbarium Management System, http://herbaria.plants.ox.ac.uk/bol/brahms/Software), a free database programme specifically for cataloguing and managing plant collections. Each specimen is assigned a reference and arranged in a chronological order. The herbarium database contains information on SSBH's entire herbarium collections and is updated regularly.

The SSBH herbarium is an important source of reference on UAE flora with the database being useful for conservation, taxonomy, flora, phenology, palynology, and other research purposes. Within the UAE, the other most important plant collections are housed in the Sharjah Natural History Museum, the Herbarium of the UAE University in Al Ain, the Herbarium of the Zayed Complex for Herbal Research and Traditional Medicine, and the National Museum of Ra's al Khaimah.

At the SSBH Herbarium, the distribution records of species are constantly revised as new data are acquired. This helps in the development of updated, computerised species-level range maps for vascular plants in the UAE, which has not, to our knowledge, otherwise been undertaken, although maps and descriptions of species range and habitats are found in flora books and other floristic studies. We consider that these biodiversity exploration and documentation activities are important for the understanding and conservation of our unique floral wealth. The SSBH can be viewed as a useful resource in identifying national collecting priorities and ensuring species diversity, as well as the preservation of the genetic diversity within a species that is included in the collections. Increased knowledge of the presence and location of species will assist us to detect, monitor, measure and predict changes in biological diversity and the impact of such changes on ecosystem functions (Wheeler *et al.* 2012).

The Sharjah Research Academy is currently in the process of establishing a state of the art plant molecular biology laboratory for the documentation and conservation of genetic resources. This would permit in depth research on the use of the DNA from UAE's native plants in different applications. The use of DNA barcoding during floristic studies at the herbaria could become a supporting tool for species delimitation and identification especially when plant specimens lack diagnostic floral or fruit characters at the time of their collection. The effectiveness of DNA

barcoding for the identification of species in the UAE flora can be tested from herbarium and freshly collected specimens. This willlead to the establishment of a comprehensive DNA barcode library, which can be useful in taxonomic clarification and other conservation purposes.

Conclusion

The recent publication of new records to the flora of the UAE by different researchers draws attention to the often unrecognised floral diversity of the country. It is important that this national heritage should be safeguarded for future generations, especially because of the threats posed by anthropogenic disturbance and climate change. Moreover, due to increased grazing pressure, the recreational use of desert areas and particularly through the increase in irrigation schemes in farms, towns and cities, the flora has changed in many areas. A regular updating of the list of UAE plant records should be viewed as a priority, to provide an up-to-date information of taxa known to occur, their status, habitat distribution and utilisation potential. This work should ideally involve liaison and collaboration between local bodies (e.g. SSBH, UAEU, ICBA and EAD) and individual researchers, and international bodies (e.g., RBG Kew, RBG Edinburgh, IUCN etc.). Still in the initial stages, the SSBH is seeking to seed bank the entire flora of the UAE, and is well-placed to play a significant role in establishing a national data bank for the country's flora.

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Short Note:

The Arabian waterscorpion (Insecta: Heteroptera: Nepidae) can fly

by Peter J. Cowan and Elaine M. Cowan

At about 08.45 h on 25 May 2016, an Arabian waterscorpion, presumably *Laccotrephes fabricii* Stål, 1868 (Cowan & Cowan 2014), was located by us in the apparently permanent 'dragonfly pool' (23° 4.5' N, 57° 21.6' E, 680 m asl, Cowan & Cowan 2013, 2014) near Nizwa, between Al Hamra and Tanuf in the Jebel Akhdar foothills, northern Oman. We remembered that it was important to observe a flying specimen to see whether it was possible for the species to fly when searching for new pools to colonise (Cowan & Cowan 2014). Walker & Pittaway (1987) had stated that *L. fabricii* cannot fly and is confined to permanent bodies of water.

The waterscorpion was in shallow water, partially in submerged vegetation (*Figure 1*). Soon after location, we caught it using a hand net and placed the waterscorpion on a white plastic plate (*Figure 2*) and then PJC's arm (*Figure 3*). EMC commented that it was best to let the surface of the waterscorpion dry out to simulate drying out of the pool. So we walked back to our seats with the waterscorpion in the net and placed the net (and waterscorpion) on PJC's knee (*Figure 4*). The waterscorpion moved its forewings slightly (*Figures 5, 6*) and then suddenly, some 15 minutes after we first found it, it flew off strongly, making a whirring/buzzing noise as it did so. It flew well away from the pool 2 to 3 metres above the ground.

Fig. 1 The waterscorpion was in shallow water, partially in submerged vegetation, at the wadi 'dragonfly pool' near Nizwa, 25 May 2016. The raptorial forelegs and respiratory tube reaching the surface are well visible. [All pictures by EMC.]

Fig. 2. The waterscorpion out of the water but appearing wet.

Fig. 3 On PJC's arm, still looking wet. Dipterists might be interested in its temporary passenger.

Fig. 4. Waterscorpion (looking drier) on net on PJC's knee.

Fig. 5. Waterscorpion slightly opened its wings. Note the animal's rostrum or beak below its head.

Fig. 6. Wings opened further, prior to takeoff.

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Call for UAE mammals data

A key issue in ecology and conservation biology is to determine how species are distributed. Knowledge of the conservation status of a species is dependent to a very large extent on the availability of data on sightings.

In the United Arab Emirates, much of the data relating to the country's mammals, both native and introduced, has been published over the years. More is to be found in personal records while there is a lack of an organised system to allow for the reporting of individual records. As a result, work on the status of individual species has adversely affected by the inability to obtain access to such records.

In the UAE, the most comprehensive wildlife database available relates to birds. Most observations of birds throughout the country by visiting and resident birdwatchers, both professional scientists and amateurs, have now been incorporated into a single database maintained and regularly updated by Tommy Pedersen, on behalf of the Emirates Bird Records Committee. The database goes back to the 1970s, with further historical records, from the 1980s and 1990s, being added.

The value of such comprehensive and easily accessible data has been clearly demonstrated; numerous conservation studies or assessments of individual species, by both local and international researchers and institutions have benefited.

No such easily-accessible database exists so far in the UAE for other taxa. Data and observations are spread among different individuals, institutions, only some of which has been published or is accessible. Other records have been lost or their existence has been forgotten.

The writer now plans to start co-ordinating all available data on mammals, whether current or historical data, using Wildlife Recorder, the same database structure used for bird recording.

The first part of the work will be to populate the database with new records while trying, at the same time, to add all published historical data that can be located. This work has already been initiated for the Bat fauna of UAE. Achieving a comprehensive and more or less exhaustive UAE Mammals database will take time, but there is an obvious need to do it, if an efficient conservation strategy of mammal species in the UAE is to be possible.

All type of data are welcomed (single observations or data files, in Excel sheet, word document…)

Records can be sent directly to Jacky Judas jackyjudas@gmail.com or may be posted on the UAE Mammals thread of the UAE Birding Forum: http://www.uaebirding.com/forum/forumdisplay.php?12-UAE-mammals

To ensure their value, all observations should include at least the following information: species, date, location (as accurate as possible, and ideally geographical coordinates expressed as latitude and longitude), number of individuals observed, observers' name and contact details. Any additional comments on the conditions of observations, species identification process, habitat, behaviour, sex and age ratio will eventually provide more value to the record. Observers' name will always been kept in the database. I t should be noted, however, that by provision of their data, observers accept that their records will be freely available to be used for conservation and research purposes.

All mammal species are of interest, including both native species and non-native introduced species. With raising concern on the impact of non-native and potentially invasive species on natural habitats and ecosystem balance, it becomes increasingly important to get access to quantitative information on species occurrence, including not only their presence, but also details of abundance, distribution and trends. All feral species, like goats, donkeys, dogs and cats, (the latter outside urban areas), or introduced species, commensal or not, such as mice, rats and squirrels (or more exotic ones), are important to report, to keep tracks on their population dynamics and successful naturalisation, if any, for non-domestic species.

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تريبيلوس

ملاحظات إلى المساهمين

تريبيلوس هي مجلة تصدر منذ العام 1991 عن جمعية الإمارات للتاريخ الطبيعي التي تأسست في أبو ظبي في العام 1976 لتكون أول منظمة بيئية غير حكومية في دولة الإمارات العربية المتحدة, وتتبع لها كل من جمعية الإمارات للتاريخ الطبيعي في العين وجمعية دبي للتاريخ الطبيعي.

وقد قامت الجمعية خلال الفترة ما بين 1976 و 1990 بإصدار 42 عددا من النشرات الخاصة بها وذلك بمعدل ثلاثة أعداد سنويا.

تتوفر أعداد تريبيلوس والنشرات على الموقع الإلكتروني لجمعية الإمارات للتاريخ الطبيعي في العين: www.enhg.org

بعد ذلك أصبحت تريبيلوس تصدر مرتين سنويا وبقياس ورق الطباعة العادي خلال الفترة الممتدة بين العامين 1991 و 2006, ثم شهدت اعتبارا من العددى 17 (2007) زيادة في عدد صفحاتها وباتت تصدر سنويا.

تهدف المجلة إلى تكوين مجموعة من السجلات والمقالات وأوراق العمل المتعلقة بمواضيع ذات صلة بالتاريخ الطبيعي والتراث والجيولوجيا وعلم الإحاثات وعلم الآثار وتاريخ المنطقة الجنوبية الشرقية من شبه الجزيرة العربية, مع التركيز على دولة الإمارات العربية المتحدة والمناطق المجاورة.

ترحب المجلة بالمقالات والملاحظات والتعليقات القصيرة وغيرها من مساهمات المقيمين بدولة الإمارات العربية المتحدة أو غيرهم, على ألا يكون قد جرى نشرها في مكان آخر, وذلك وفق التعليمات المذكورة أدناه.

إن المعلومات الواردة في المجلة دقيقة بقدر ما يمكن لهيئة التحرير واللجنة الاستشارية أن تحدده, ولا تعبر النصوص الواردة فيها إلا عن رأي مؤلفيها فقط.

تتم مراجعة جميع النصوص المرسلة للمجلة من قبل أعضاء هيئة التحرير والأعضاء المختصين في اللجنة الاستشارية ومختصين آخرين.

الرجاء المراسلة والاستفسار على العنوان التالي:

المحرر

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تسليم النصوص

يجب تسليم نسخة إلكترونية من النص, على أن يسبق النص مقتطف مختصر وأن يذكر في نهايته عنوان المؤلف, بما في ذلك عنوان بريده الإلكتروني.

كذلك يجب تسليم نسخة إلكترونية من الصور والرسومات والخرائط, على أن تكون على درجة عالية من الوضوح لإتاحة الإمكانية لإعادة نشرها.

يجب إدراج المراجع حسب الترتيب الزمني لنشرها, مع ذكر اسم المؤلف وتاريخ النشر بين قوسين إلى جانب العنوان واسم الناشر وبلد النشر, ويمكن في المقالات الصحفية استخدام الاختصارات التقليدية التي تستخدم عادة في العناوين.

يجب ذكر الأسماء العلمية بعد المصطلحات اللاتينية, كما يجب إضافة الأسماء باللغة الإنجليزية واللغة العربية في حال وجودها .