TERRESTRIAL HABITATS

THE LANDSCAPE OF THE UAE IS DOMINATED mainly by low-lying, sandy desert, but extensive salt flats (sabkha) occur in coastal areas, and in the east, the Hajar Mountains rise sharply above the surrounding landscape to an elevation of about 2,000 metres. A significant proportion of the roughly 4.3 million inhabitants live in towns and cities located along the coast, leaving much of the interior sparsely populated.

The climate of the UAE is of a bi-seasonal Mediterranean type and characterised by high temperatures and low rainfall. The summers (May to October) are distinctly hot, with daytime temperatures regularly exceeding 40°C. Rainfall occurs occasionally during the summer, but is generally restricted to the cooler winter months (November to April) when temperatures can drop to 4°C in some areas at night (and even lower in the mountains). Frosts are unknown. Seasonal fluctuations in temperatures are less well pronounced along the coast, where they are buffered by the maritime influence.

Annual rainfall amounts vary according to location, but precipitation generally decreases along a north-east to south-west gradient. The mountainous areas receive most rainfall (long-term annual mean of about 154 millimetres in Masfut, ranging from 4 to 479 millimetres), about 80 millimetres in coastal areas such as Abu Dhabi and Dubai, but substantially less in more western and southern parts of the country (data obtained from Böer 1997). Even within a given region, rainfall is often highly localised, with certain areas regularly receiving lower or higher amounts than adjacent ones.

Temporal variation in the rainfall pattern is a feature which, due to the relatively low total amounts received even in wet years, has a much more decisive influence on biological activity than, for instance, in more temperate regions of the world. In some years, rainfall amounts well in excess of long-term mean values are recorded, whereas in other years there may be no significant precipitation at all. For instance, over a 23-year observation period (1970–1992) in Al Ain, total annual rainfall ranged from 1 to 303 millimetres, with a long-term mean of 100 millimetres (Böer 1997).

Rainfall is most effective for the vegetation when it occurs during the cooler part of the year, primarily because key stages of growth and development take place during this period, as outlined below (see *Plant Adaptations*), but also due to the fact that less water is lost to evaporation. Potential evaporation (i.e. that water which would evaporate if present) far exceeds precipitation in most parts of the country by a factor of about 20, indicating the high degree of stress to which organisms are exposed.

Coastal regions experience high humidity, especially in the summer months, but the interior has a much drier climate. Mists frequently cover the mountains, but are also a common occurrence in some desert regions, such as to the south and west of Abu Dhabi Island. Dewfall is a common phenomenon in coastal localities. Many plants on coastal dunes have shallow, lateral rooting systems that enable them to exploit this regular input of moisture.

Due to the harsh climatic conditions, soils are generally extremely poor in organic matter, and biological activity is low. The properties of the little-altered parent material (sand, silt, gravels, bedrock) therefore exert a dominant influence on species composition of the vegetation, and in turn, on the fauna in most parts of the country. Although these soils are often rich in certain nutrients, they are highly deficient in nitrogen, primarily due to the lack of organic material. Soil fertility is therefore extremely low.

Soil salinity is a factor restricting or exerting a highly selective effect on plant growth not only in many coastal areas, but also inland, particularly on interdunal plains. Problems of salinity have been exacerbated in recent decades due to a more widespread use of irrigation water and inappropriate land-use.

As much of the landscape is too inhospitable for human activities, natural terrestrial habitat types occupy by far the larger part of the country. These can be broadly classified as follows: inland sand sheets and dunes; piedmont alluvial and interdunal plains; mountains and wadis; coastal sand sheets with dwarf shrub vegetation; and coastal and inland sabkha. Important anthropogenic habitat types, such as oases, farmland, forestry plantations and urban areas account for a relatively small proportion. These major habitat types can often be further subdivided into more specialised ones, each with their own specific abiotic features, vegetation and fauna.

Vegetation is one of the key attributes of the landscape, and as primary producers, plants provide the food on which all organisms ultimately depend, either directly (as in the case of herbivores) or indirectly. Most major habitat types are characterised by certain plant assemblages, a notable exception being sabkha. The severe climatic conditions, though, mean that vegetation cover is generally sparse, particularly in areas with exceptionally low rainfall, and has been further reduced by severe overgrazing. The limited number of plant species involved, the relatively broad ecological tolerances of many key perennials and the fact that some potentially suitable species do not appear for years under unfavourable rainfall conditions, are factors that serve to complicate vegetation classification in many desert habitats. Communities tend to be named after the dominant perennial species present, sometimes along with the co-dominant species. There has been some attempt to describe, delimit and classify certain vegetation communities according to the phytosociological approach of Braun-Blanquet (1928), as commonly practised in Central Europe, but such studies remain few in number, probably due to the inherent difficulties outlined above. Roshier *et al.* (1996) used multivariate procedures to obtain a basic classification of some important plant communities of the desert interior of the UAE. However, all these attempts remain preliminary.

MAJOR TERRESTRIAL HABITAT TYPES AND THEIR VEGETATION

COASTAL ZONE

The coastline of mainland UAE extends for about 650 kilometres, and comprises the Arabian Gulf coast in the north, and the Gulf of Oman coast to the east. The Arabian Gulf coastline is predominantly flat, with warm, shallow waters. Natural deep-water harbours occur mainly on the eastern coast. The UAE possesses at least 200 islands, most of which are rather small and flat. However, Zirku Island attains a maximum altitude of 160 metres, even though it is only about 8 square kilometres in size.

Specialised habitats of the coastal zone include mangroves, saltmarsh, tidal flats with cyanobacterial mats, sandy and rocky beaches, coastal flats and low sand dunes, sabkha, cliffs and rocky headlands.

Halophytic perennials predominate in the coastal vegetation, although locally, annuals such as *Biernertia cycloptera*, *Suaeda aegyptiaca* and *Zygophyllum simplex* may be more conspicuous. Succulent, semi-woody dwarf shrubs are the main life-form, with most species belonging to the Chenopodiaceae. Widespread species include *Arthrocnemum macrostachyum*, *Halocnemum strobilaceum*, *Halopeplis perfoliata*, *Salsola drummondii*, *S. imbricata* and *Suaeda vermiculata*. Members of the genus *Zygophyllum* (Zygophyllaceae) are also a conspicuous feature of many coastal locations, and mangroves are developed in a number of intertidal areas. True grasses (Poaceae) also play an important role in the vegetation cover, especially salt-tolerant representatives of the genera *Sporobolus* and *Aeluropus*.

Zygophyllum qatarense is the host plant of two striking parasitic plants, namely *Cynomorium coccineum* and *Cistanche tubulosa*. The two species are particularly common along the coastal areas, but also occur inland. Furthermore, *Cistanche* is frequently associated with *Haloxylon salicornicum* and appears abundantly in wet years or where there is a regular supply of water. Occasionally it even grows on the roots of *Arthrocnemum macrostachyum* and *Halocnemum strobilaceum*.

Seagrasses are a unique group of plants because they are the only flowering plants capable of thriving permanently submerged in the sea. Three species are known to occur in the coastal waters of the UAE, *Halodule uninervis*, *Halophila ovalis* and *H. stipulacea* (see the chapter on *The Shore and Shallow Seas*). Although often overlooked due to their marine existence, even casual visitors to beaches will be familiar with seagrass litter that is washed up in large quantities at the water's edge. This litter provides important microhabitats for numerous coastal organisms, and it contributes to the soil development of coastal substrates (Phillips 2002).

Coastal vegetation is extremely productive, especially when compared to other terrestrial habitats in the UAE. Despite the fact that the vegetation is home to a relatively high number of species, the individual stands tend to be species-poor or even monospecific, i.e. carpets of one

TOP LEFT: Cynomorium coccineum
BELOW: Cistanche tubulosa

ABOVE: *Low coastal dunes with the halophytic chenopod* Halocnemum strobilaceum *growing in the foreground.*
LEFT: Arthrocnemum macrostachyum *is another halophyte commonly found along the UAE coastline.*

particular species usually dominate over large areas. The main factors controlling the distribution of plant species and community composition along the coast are:

- salinity of the water and/or substrate
- frequency and extent of inundation
- the water-holding capacity of the substrate.

Often, a distinct zonation of the vegetation can be readily observed. Where there is pronounced small-scale heterogeneity in abiotic factors, the vegetation forms corresponding mosaics.

An overview of the zonation of coastal vegetation of Arabia is provided by Deil (2000). The halophytic vegetation of the UAE corresponds mainly to the situation he describes for Qatar, with species such as *Arthrocnemum macrostachyum*, *Halocnemum strobilaceum* and *Halopeplis perfoliata* very common in salt-marsh environments (i.e. with frequent inundation), and *Suaeda vermiculata* and *Limonium axillare* in more specialised conditions. *Salsola drummondii* is locally common on the coastline, growing on slightly raised barrier berms created by tidal action and occasionally on coastal jebels.

Juncus rigidus is a very local species that occurs predominantly in a coastal salt marsh between Dhayah and Rams (Ra's al-Khaimah), where it forms dense, monospecific stands.

Mangroves are well-developed along parts of the UAE coastline, and impressive stands can be observed at a number of localities, including Abu Dhabi Island. Further information on mangal communities is given in the chapter on *Life in the Mangroves*.

LEFT: Halopeplis perfoliata *is the most salt-tolerant halophyte in the UAE.*
BELOW: *A flooded sabkha plain*

COASTAL AND INLAND SABKHA

Sabkha is an Arabic term referring to flat, salt-encrusted desert that is usually devoid of any significant plant cover. The high concentration of salts on the sabkha surface prevents the growth of most plant species, and as a consequence, landscapes dominated by sabkha appear distinctly barren. This accumulation of salt is possible in areas where the water table lies close to the surface, as outlined in the chapter on *The Quaternary Deposits*. As a broad distinction, it is possible to distinguish between coastal and inland sabkha. With the former, saline water is provided by the tidal action of the sea, with the latter, episodic flooding takes place after the infrequent rainfall events, sometimes leading to the formation of large ephemeral lakes.

A detailed, up-to-date overview of sabkha ecology has recently been produced by Barth and Böer (2002), and a contribution specifically dealing with the sabkha vegetation of the UAE is expected shortly (Brown 2005).

Plant species associated with sabkha are restricted mainly to the margins, with halophytes predominating. Some plants are able to germinate on the sabkha surface after heavy rainfall, because this leads to a temporary reduction in salt concentrations. For instance, the moderately salt-tolerant *Zygophyllum qatarense* can germinate under such conditions, and once the plants have gained a foothold, they can probably survive for years in a state of dormancy by discarding their succulent leaves. After further heavy downpours, they develop new leaves and resume growth.

Chenopods are the main constituents of the vegetation in more saline coastal habitats, and important species are listed above. Further inland, where the influence of the sea recedes, *Zygophyllum qatarense* often covers wide expanses in which other species are occasionally interspersed.

The coastal white dunes are home to a high diversity of plants, including a profusion of annuals that thrive after winter rains. Dwarf shrubs and perennial grasses dominate the vegetation physiognomically. An informative transect through the coastal dunes and sabkhas in the vicinity of Dubai was described by Deil and Müller-Hohenstein (1996). The dunes close to the coast are colonised by a local community in which the dwarf shrubs *Sphaerocoma aucheri* and *Cornulaca monacantha* are important constituents. The vegetation of the dunes is treated in more detail below (see *Sand Sheets and Dunes*).

Chenopods are typically found on the edges of sabkha, including *Agriophyllum minus*, *Arthrocnemum macrostachyum*, *Bienertia cycloptera, Salsola imbricata* and *Seidlitzia rosmarinus*. *Halopeplis perfoliata* is probably the most salt-tolerant of halophytes and common in moist depressions around coastal sabkha. It also occurs on inland sabkha in some areas, such as in the vicinity of Sweihan and the Liwa Crescent. The plants often turn red, and are therefore easily spotted. The tamarisks *Tamarix aucheriana* and *T. nilotica* are found both on coastal and inland sabkha. *Limonium axillare*, a common psammophytic shrub along some stretches of the coastline, is also occasionally encountered on inland sabkha, especially where there is a thin veneer of sand on the surface. The chenopod *Anabasis setifera* is a characteristic pioneer species of reclaimed sabkha in coastal areas.

Anabasis setifera

SAND SHEETS AND DUNES

Sand sheets and dunes of different types cover by far the largest proportion of the UAE, ranging from vast, flat expanses to the impressive mega-dunes which are a prominent feature, especially in the south of the country.

As a broad generalisation, it is possible to distinguish between two types of sand based on its source. Coastal white sands are derived from recent marine sediments and are rich in carbonate. Apart from dominating many coastal areas, drifts of wind-blown white sands are occasionally found up to 50 kilometres from the present coastline. Cemented sand dunes forming rocky outcrops occur in many scattered localities along a broad coastal zone. The siliceous sands that cover large tracts of the inland are the product of a long process of weathering of quartz. This substrate is poor in carbonate and varies in colour. Sand grains that have a coating of haematite (iron oxide) range from pink to red in colour, depending on the thickness of this coating. Otherwise the siliceous sands are yellowish to grey. The lack of carbonate probably has an important influence on vegetation composition.

In contrast to the situation in more temperate regions of the world, sand, especially where it is stable, provides a favourable substrate for plant growth in warm, arid to semi-arid climates. This can be attributed primarily to water being held immediately below the surface, a process that is greatly aided if there is a certain amount of silt (finer-grained substrate) in the subsurface layers, as is often the case with stabilised sand sheets. Although the surface layers may dry out rapidly due to evaporation, water can be held in the subsurface for considerable periods of time, where it remains available for plant roots. In other words, such sand sheets act as reservoirs for water in the short to medium term.

Cemented sand dunes form rocky outcrops in scattered localities along the coastline.

However, unstable sandy substrates, such as mobile dunes, are less amenable to plant growth for two main reasons. First, these substrates are composed almost entirely of relatively coarse-grained sand, and this allows the rapid penetration of water to greater depths where it is then inaccessible for many plants. However, there is often a distinct zone of plant growth developed at the base of such dunes due to water seepage. Second, only a few species can come to terms with the constantly changing surface conditions of mobile sandy substrates. Seeds that become buried deep in the sand are not able to germinate. Plants that do germinate have to be resistant at the highly sensitive seedling stage to a variety of adverse conditions, such as lack of water, abrasion from wind-blown sand (sand-blasting) and frequent burial and the removal of sand from around them. Mobile sands are therefore usually very sparsely vegetated by perennials, and the contribution of desert annuals, even after heavy rainfall, is generally insignificant, both in terms of species numbers and cover.

ABOVE: Silene villosa. BELOW: Calligonum comosum

Coastal white sands, which tend to be rather stable, often have a relatively high coverage of vegetation. Of particular importance are the open xeromorphic grasslands dominated by the perennial tussock grass *Panicum turgidum,* which form what has been described as a 'coastal white sand community'. This community extends along a narrow coastal band northwards into Kuwait. In the UAE, common perennial associates include the dwarf shrubs *Sphaerocoma aucheri, Cornulaca monacantha, Heliotropium bacciferum* and *Rhanterium epapposum* (locally), as well as the graminoids *Coelachyrum piercii, Panicum turgidum, Pennisetum divisum, Stipagrostis plumosa and Cyperus arenarius*. Coastal sands are often rich in annuals, particularly after wet winters, with species such as *Eremobium aegyptiacum*, *Lotus halophilus*, *Neurada procumbens*, *Plantago boissieri* and *Silene villosa* sometimes abundant.

Rhanterium epapposum was once a common dwarf shrub in many north-eastern parts of the country, and the main component of the *Rhanterium epapposum* community. Deil and Müller-Hohenstein (1996) state that it was still common in low dune systems in Dubai Emirate as recently as 1987. Overgrazing has led to the disappearance of the species in many locations, and even where it still persists, it is often only possible to find flowering plants where they are protected from grazing.

Further inland, as the maritime influence diminishes, vegetation cover of the sands becomes more patchy, but not necessarily less interesting, and a number of important communities can be encountered.

Prosopis cineraria (*ghaf*) is an impressive tree occurring in dunes in the eastern part of Abu Dhabi Emirate where it forms characteristic groves ('*ghaf* forests', *Prosopis cineraria*-community). Further eastwards, it also occurs locally on alluvial plains. The western distribution limit of this species on the Arabian Peninsula is between Sweihan and Abu Dhabi. Natural forests are deteriorating rapidly, due to direct destruction and disturbance, but also on account of excessive water extraction and serious overgrazing. The latter in particular appears to be preventing natural rejuvenation of the stands. Although germination could take place after heavy rainfall events, it is doubtful whether the seedlings would survive the voracious appetite of the ubiquitous goats, sheep and camels, especially as livestock camps have been established near or in many *ghaf* forests. Young trees that do become established invariably originate from root suckers, often some distance from the mother plant, i.e. by vegetative means.

The sedge *Cyperus conglomeratus* is one of the most ubiquitous species of sands in the UAE. It forms monotonous, species-poor to species-rich stands over large areas (*Cyperus conglomeratus*-community). Typical accompanying perennials include *Dipterygium glaucum* and *Limeum arabicum*. *Cyperus* itself is also a common associate in other communities. As it is generally less palatable, the species has almost certainly been able to withstand the heavy grazing characteristic of recent decades better than some true grasses, such as *Centropodia forskalii*, *Panicum turgidum* and *Pennisetum divisum*. Observations in the Al Wathba Protected Area indicate that mass germination of *Cyperus* takes place after heavy rainfall in the late spring, when temperatures are already quite high again. However, many seedlings will die prematurely if sufficient rainfall is not forthcoming to sustain growth during the sensitive early stages of establishment.

Moving into the southern half of the country, *Cornulaca arabica* is the key species of a characteristic dwarf shrub community on the lower flanks of dunes in the Rub' al-Khali. This *Cornulaca arabica*-community, in which *Cyperus conglomeratus* also plays a prominent role, is widespread throughout the Liwa Crescent, Umm al-Zumul and the south-west. The precise taxonomy of *Cornulaca* is not entirely clear: some authors regard it as conspecific with *C. monacantha*, but others, including Mandaville (1990) and ourselves, treat it as a distinct species that is endemic to the Rub' al-Khali, extending locally into the northern part of Abu Dhabi Emirate.

Another characteristic plant of the Rub' al-Khali and one that appears to be widespread in the Liwa/Umm al-Zumul area is *Calligonum crinitum*, a species that has been largely overlooked in the UAE and confused with *C. comosum*. Mandaville (1990) suggests that the former is typical of the higher dunes of the Rub' al-Khali, whereas the latter is associated with lower dunes and sand sheets further north.

Prosopis cineraria *(ghaf) establish themselves some distance from the mother plant by means of root suckers.*

HALOXYLON PERSICUM COMMUNITY

Stands of the shrubby tree *Haloxylon persicum* (*ghada*) occupy a geographically distinct and well-delineated area south of Abu Dhabi City, where they form a characteristic species-poor plant assemblage (*Haloxylon persicum*-community), in which *Haloxylon salicornicum* is co-dominant, at least locally. Frequent fog in the region enables the growth of lichens on the bark of *H. persicum* shrubs (see page 156). The vegetation of these 'dew-forests' (Aspinall and Hellyer 2003) is able to comb out droplets of water from the atmosphere, which then fall to the ground beneath the plants. The same 'auto-watering mechanism' has been described from other parts of the world, for instance from the montane pine forests on the Canary Islands (Kunkel 1993).

The stands of *Haloxylon persicum* are of outstanding conservation value due to the limited extent of their distribution in the UAE, especially as they appear reasonably intact. Similar stands also occur locally in the central and northern parts of Saudi Arabia, as well as in the Eastern Province, but apart from the one area reported for the UAE, the species appears to be absent from south-east Arabia.

Haloxylon persicum

Haloxylon salicornicum

TRIBULUS ARABICUS

Tribulus arabicus (*Tribulus 'omanense'*) is a perennial herb that is widespread on deep, undulating sand sheets in the southern half of the country, sometimes forming extensive stands (*Tribulus arabicus*-community), and is invariably accompanied by *Cyperus conglomeratus*. The morphological variability of *T. arabicus* plants, even amongst those growing in close proximity to each other, has resulted in much taxonomic confusion. For this reason, the species that is now often referred to as '*Tribulus omanense*' in the UAE is probably best regarded as belonging to the *T. arabicus*-complex. Irrespective of its precise identity, it is an extremely important grazing plant for domestic livestock and possibly also for wild gazelles.

Right: *An example of* Tribulus-Cyperus *vegetation*

PIEDMONT ALLUVIAL AND INTERDUNAL PLAINS

Plains are a common landscape feature in many parts of the UAE. In the vicinity of the Hajar Mountains, they occur as wide, flat expanses that are covered in alluvial detritus consisting of coarse rocks, pebbles and gravels. As a broad generalisation, the substrate of the alluvial plains becomes finer with increasing distance from the mountains, with sand also often present. Significant deposits of pebbly substrate also occur in the far west near Sila'a and around Sabkha Matti, probably originating from the highlands of western Saudi Arabia.

In other parts of the country, plains are intimately associated with dune systems, where they form a loosely connected network of interdunes of varying size. The substrate of these interdunes is sandy to gravelly, depending on the location, and often displays elevated levels of salinity compared with the adjacent sand dunes. Firm crusts of *gatch* can also form due to evaporative processes, creating a mosaic of different types of substrate. Inland sabkha is frequently developed where the groundwater occurs close to the surface, or in larger depressions in which rainwater accumulates. On the edges of some plains, rocky outcrops have been exposed by deflation.

The physiognomically dominant vegetation of the alluvial plains is characterised by small trees, dwarf shrubs and succulents. The typical species of rocky and gravelly plains in the north-eastern part of the UAE is *Acacia tortilis* (*samr*), a flat-topped tree that forms extensive stands (*Acacia tortilis*-community). Good examples of open *Acacia* woodland can be seen on the Al Madam Plain or on the east coast. The species is also the most conspicuous floristic component of the lower mountain ranges, especially up to about 200 to 300 metres a.s.l. Common associates include the shrubs *Lycium shawii* and *Gaillonia aucheri* (= *Jaubertia a.*), as well as the succulent *Euphorbia larica* and semi-succulent *Ochradenus arabicus*. In eastern parts of the country and in Oman, *Prosopis cineraria* and *Acacia ehrenbergiana* regularly occur together with *A. tortilis* on alluvial plains. *A. ehrenbergiana* also occurs on sandy to silty interdunal plains in a few scattered localities in the east of Abu Dhabi Emirate and in Dubai and Sharjah Emirates.

ABOVE: Lycium shawii
BELOW: Acacia tortilis-*community*

Rhazya stricta (*harma*) is generally regarded as a gravel plain species, and one that is restricted to the east of the country, for instance around Al Wagan and Jebel Hafit. Due to its toxicity, it is shunned by grazing animals, and as a result, has probably increased in recent decades as a direct consequence of overgrazing of more palatable species. Sand deflation, resulting from the decline of dwarf shrubs and grasses, has probably also contributed to the expansion of *Rhazya*. The '*Rhazya stricta*-community' can be regarded as a degradation stage of other communities, such as those of *Acacia tortilis* and *Haloxylon salicornicum*. Both *Haloxylon salicornicum* and *Aerva javanica* are often associated with *Rhazya*.

Calotropis procera (*ushar*), an extremely fast-growing, toxic tree that can begin flowering at an early age, is a species of sandy gravel plains, often where there is a a lot of human disturbance. It is abundant in some parts of the country, particularly in the north-east. For instance, large populations of this species fringe the roads north of Al Ain towards Dubai and Sharjah. Further west, it becomes increasingly rare, with only isolated occurrences.

LEFT: *The semi-succulent* Ochradenus arabicus *commonly grows in association with stands of* Acacia tortilis.
RIGHT: Calotropis procera *is abundant in the north-east of the UAE.*

A number of shrubs and dwarf shrubs play an important role in the vegetation of both alluvial and interdunal plains. *Haloxylon salicornicum* is a chenopod found predominantly throughout the north of the Arabian Peninsula where it is the main constituent of the *Haloxylon salicornicum*-community, dominating extensive tracts of desert. In the UAE, it occurs in the northern half of the country where it is common on sandy, gravelly and rocky plains, as well as gently undulating sand sheets. It is conceivable that *Haloxylon salicornicum* is one of several species that may have benefited somewhat over recent decades as a result of increased grazing pressures, as it is less palatable than, for instance, *Rhanterium epapposum* or *Panicum turgidum*. However, in the absence of other species, camels may browse this shrub heavily and could, therefore, contribute towards its decline.

Despite its name, *Haloxylon salicornicum* is only slightly tolerant of salt, and as a result, is absent from communities in which halophytes play a major role. As the salinity of the soil increases, the species is replaced by either *Zygophyllum qatarense* or *Z. mandavillei*, but an intergrading of *Haloxylon* and *Zygophyllum* can be observed over large areas where soil conditions allow, with *H. salicornicum* usually confined to the slightly higher, less saline ground, and *Zygophyllum* to depressions.

Zygophyllum qatarense regularly dominates on interdunal plains that are influenced by elevated soil salinity. Deil (2000) indicates that *Zygophyllum mandavillei*, a very similar species to *Z. qatarense* and one that was thought to be widespread in the interior of the UAE, is actually restricted to a small area of southern Arabia.

Other regular associates on interdunal plains include the perennials *Fagonia ovalifolia*, a small woody plant, *Heliotropium digynum*, found mainly on sandy interdunal corridors, and *H. bacciferum*, a plant which tolerates more saline, gravelly substrates.

The rather species-poor annual vegetation of the interdunal plains is dependent on winter rainfall. In years of low precipitation, desert annuals may not even geminate at all. High soil salinity is another factor that restricts the potential occurrence of many annuals. Inland sabkha is frequently developed in the interdunes, and vegetation may be completely lacking there.

MOUNTAINS AND WADIS

The Hajar Mountains, the major mountain system of south-eastern Arabia, extend some 700 kilometres from the Musandam Peninsula in the north to close to the Wahiba Sands (eastern Oman) in the south-east. These mountains transverse the UAE from north to south in the east of the country, near to the Gulf of Oman coast. The main watershed runs along this north–south axis, so that alluvial debris has been deposited along a parallel strip at the base of the mountains on either side. These layers of alluvium have important repercussions for vegetation development, as already described.

The mountains rise abruptly and are dissected by numerous wadis. Apart from small pockets of humus that are able to accumulate in rock fissures, the protection of rocks and other sheltered locations, there has been virtually no development of humus-rich soils on the mountain slopes, leaving the underlying parent material exposed.

Due to the sparseness of perennial vegetation cover, the spectacular mountain scenery often appears distinctly barren at first sight. However, this initial impression is misleading, because many wadis and the high mountain plateaux can support a relatively lush vegetation. Furthermore, the mountainous areas contain the highest diversity of plant life compared to any other habitat type in the UAE, with composites (Asteraceae), grasses (Poaceae) and umbellifers (Apiaceae) represented by a relatively high number of species.

On the lower mountain slopes, *Acacia tortilis* and *Euphorbia larica* are ever-present, and accompanied by a number of perennials such as *Gaillonia aucheri*, *Lycium shawii, Pulicaria glutinosa*, *Ochradenus aucheri*, *Physorrhynchus chamaerapistrum* and *Tephrosia apollinea*. *Capparis cartilaginea* and *C. spinosa* are two species with large, leathery leaves that occur throughout the mountains, the former often hanging from calcareous rocky cliffs.

With increasing elevation, *Acacia* gradually disappears and is rarely encountered above 500 metres, although *Euphorbia* remains common at much higher altitudes. Trees, such as *Moringa peregrina* and *Ficus cordata* ssp. *salicifolia,* become more prominent on rock debris, especially near wadis. The shrub *Dodonaea viscosa* is

ABOVE: *A wadi in the Hajar Mountains*
RIGHT: Blepharis ciliaris *is a widespread plant of rocky habitats in the mountains.*

LEFT: *Arabian almond* Amygdalus arabica *occurs above 1,000 metres in the north-eastern UAE.*
BELOW: Nerium oleander *is found in canyon-like wadis at higher altitudes.*

widespread and common throughout the mountains, often reaching the summits. In the far north-east of the country, the Arabian almond (*Amygdalus arabica*) is an important constituent of the vegetation above 1,000 metres. Further south, olive trees (*Olea europaea*) are locally common in high mountain situations.

Increased precipitation and lower temperatures lead to a more favourable climate for plants at higher altitudes. This is most vividly documented by the conspicuous presence of poikilohydric plants, in particular lichens and bryophytes (page 156). The widespread mountain fern *Onychium divaricatum* is also a sure indicator of more favourable mesoclimatic conditions.

Wadi beds are often extremely rich floristically, especially in their lower reaches, where a combination of different types of substrate, pronounced spatial heterogeneity in microtopography and microclimate, light availability and regular access to water create a mosaic of favourable microhabitats. *Acacia tortilis* fringes the margins of many wadis, regularly occurring in wadi beds on elevated banks, and is frequently accompanied by *Lycium shawii* and *Gaillonia aucheri*. The latter is often associated with the superficially similar *Pteropyrum scoparium* in wide wadi beds, as well as on adjacent gravel plains and rocky slopes. *Zizyphus spina-christi* (Christ's thorn) is a common tree in wadis and on rocky slopes at lower altitudes, ascending to about 1,500 metres. In contrast, *Acridocarpus orientalis* is a small tree only known from Jebel Hafit in the UAE, where it grows in the upper reaches of Wadi Tarabat. In wet winters, the wadis abound with a profusion of annuals, and particularly common, even in drier years, is *Asphodelus tenuifolius*, a lily-like plant with numerous small white flowers. The only known species of orchid in the UAE, *Epipactis veratrifolia*, thrives in moist shady conditions along the banks of wadis and artificial watercourses, typically accompanied by the fern *Adiantum capillus-veneris*.

Nerium oleander (oleander) and the grass *Saccharum ravennae* form a distinct community in the deeply incised, canyon-like wadis at higher altitudes, as described by Deil and Müller-Hohenstein (1996).

Above left and right: Falaj *irrigation channels*
Below: *Al Wathba lake near Abu Dhabi Island*

FRESHWATER HABITATS

Natural freshwater habitats are generally rare in the UAE, being largely confined to the mountains where there are a number of permanent streams and rockpools. Typical aquatic plants encountered in such locations include *Potamogeton lucens*, *P. pectinatus*, *Najas marina* and *Zannichellia palustris*. *Arundo donax* and *Juncus socotranus* occur in moist conditions throughout the mountains. Temporary streams are more common, with wadis carrying flowing water for a few hours after heavy rainfall. Depending on the subsequent weather conditions, the pools that remain after rain may persist for weeks or months, before eventually drying out.

A number of artificial aquatic habitats have been created in recent years, such as Al Wathba Lake near Abu Dhabi Island. This lake, now a protected area, contains a mixture of brackish and fresh water. *Phragmites australis* (reed), a cosmopolitan species, forms dense stands there. The species is tolerant of salinity, but sensitive to water movement, which is why it is most often found by standing bodies of water, including smaller ones, even on damp ground caused by excess irrigation water. Members of the genus *Tamarix* (tamarisks) are characteristic of saline habitats where the water table is close to the surface, often far inland.

OASES AND MODERN AGRICULTURAL FARMS

Freshwater oases are found scattered throughout the country, for instance on the plains on either side of the Hajar Mountains, and in many desert locations of Abu Dhabi Emirate. The largest desert oasis occurs in the Liwa Crescent, which is in fact a series of individual oases stretching for more than 100 kilometres.

Above: Melilotus indica
Below: Sporobolus spicatus

Of significant cultural interest are the irrigation systems used to provide water for the oases. On the piedmont and coastal plains, oases are usually irrigated by a *falaj* system. Underground water is tapped from the edge of the mountains and then diverted along open channels to its point of destination, a system that dates back at least 3,000 years in the UAE. With the corresponding *ghayl* system in the mountains, water is extracted from the upper reaches of the wadi bed, fed along open watercourses built into the sides of the wadi and channelled to terraced fields.

Apart from date-palm plantations, fields in the mountains provide habitats for many wild species, especially when they are left fallow. Associated with these agricultural habitats are a host of plant species that are able to take advantage of the more favourable moisture conditions and shade afforded by the cultivated plants. Farms have sprung up in desert areas where there is a sufficient water supply (e.g. Liwa), and fields of *Chloris gayana* (Rhode's grass) are dotted around the country. Typical wildflower species of the agricultural areas include *Anagallis arvensis*, *Chenopodium murale*, *Eruca sativa, Euphorbia peplus, Fumaria parviflora*, *Melilotus indica*, *Portulaca olereaca*, *Oxalis corniculata*, *Rumex dentatus*, *Sida urens*, *Sisymbrium erysimoides*, *S. irio, Sporobolus spicatus* and *Vicia sativa*.

In recent decades, intensive efforts have been undertaken to establish forestry plantations, especially in Abu Dhabi Emirate. Many of the tree species used in these plantations are indigenous, and numerous wild species, both animal and plant, have been able to take advantage of this new type of habitat. However, for various reasons, not least for the sheer amount of water needed to sustain the trees, these plantations remain of highly dubious ecological benefit.

URBAN ENVIRONMENTS

The rapid expansion of urban areas in recent years has inevitably resulted in the destruction of large expanses of pristine landscape. However, a whole range of species, both plants and animals, has been able to invade newly-created urban habitats, often profiting from large-scale greening programmes and the widespread use of irrigation water. Some of these plant species are indigenous to the UAE, including *Aeluropus lagopoides* and *Sporobolus spicatus* (both common in irrigated urban areas), others, such as *Cressa cretica* (garden beds), *Coronopus didymus* and *Fimbristylis* sp. (both locally abundant in lawns in Abu Dhabi), *Euphorbia prostrata*, *E. serpens* and *Sonchus oleraceus*, probably not. Urban habitats offer a fascinating opportunity for studying 'invasive' species, especially as investigations so far have been fairly limited.

Gary Brown and Benno Böer

GLOSSARY

Graminoid: a term used for referring to grass-like species, including the true grasses (Poaceae) and sedges (Cyperaceae).

Halophyte (halophytic): plants able to tolerate high levels of salinity, usually through means succulence or specialised glands that secrete excess salt.

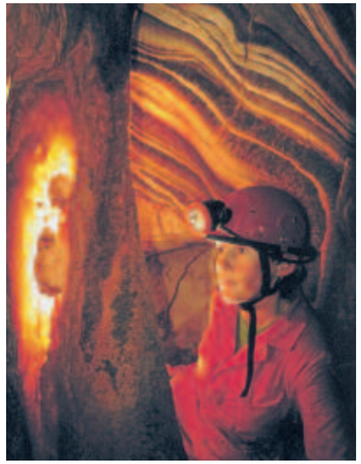
Phreatophyte: a plant that is largely dependent on the groundwater for its water supply.

Spp. species: e.g. *Zygophyllum* spp = species of *Zygophyllum*. Not to be confused with 'ssp.' (subspecies).

Transpiration: the loss of water vapour through stomata (specialised pores) in above-ground plant organs. This release of water vapour can be controlled in some species very efficiently, in many others less so.

THE CAVE FAUNA OF JEBEL HAFIT

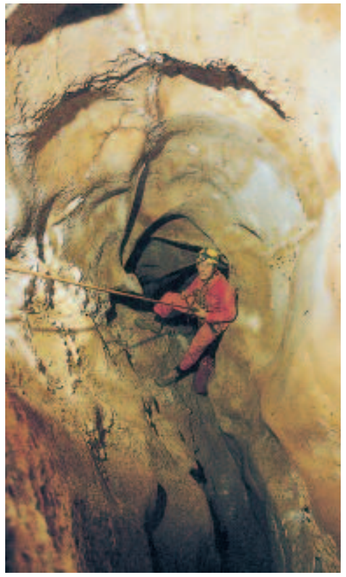
THE JEBEL HAFIT CAVE SYSTEM, Magharah Qasr Hafit, was sealed off and completely unknown to the outside world until 1996, when earth-moving equipment removed a cap of rock and revealed a large cavity. Stones dropped into this were heard to keep falling for quite some time. Olivia Pozzan was the first person to enter the cave, that same year, as part of Brian Goggin's team. On her second visit, with Tony Waltham, and Tim and Pam Fogg in 1997, Pozzan noticed a number of colourless animals on the floor of narrowing 'Labyrinth' passageways beyond the chambers known by then as the 'Red Room' and 'Crystal Ballroom'. A survey team, including Pozzan and Aspinall, was assembled in 2000 to collect some of these individuals for scientific determination, successfully employing the technique of smearing Danish Blue cheese on the cave walls to lure the hapless cave-dwelling troglobites out of inaccessible cracks and crevices. Mammal bones noticed previously in the cave floor deposits were also targeted for collection. This particular cave system has not been visited since.

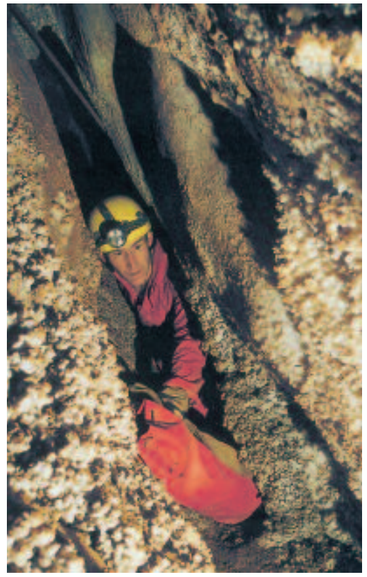


Magharah Qasr Hafit is a cave system located just west of the summit ridge of Jebel Hafit, the karst limestone mountain south of Al Ain (Waltham and Fogg 1998; Fogg, Fogg and Waltham 2002). The cave contains over 450 metres of explored shafts, passages and chambers reaching a depth of 96 metres below ground. Chambers known as the 'Red Room', 'Crystal Ballroom' and 'Labyrinth' are located between 75 and 96 metres below the entrance. The relatively constant temperature of the cave air is close to 32°C, with humidity of nearly 100 per cent.

A visit to Magharah Qasr Hafit was made in June 2000 to investigate the cave biology and to collect a stalagmite sample that was subsequently dated to 337,000 years. The passages are much older, and originate from either a wetter past environment or a phase of hydrothermal activity (Fogg, Fogg and Waltham 2002). Fauna included the remains of various bat species and living bristletails that are unpigmented and may be unique. Other fauna and flora collected included a small fox, an isopod (also unpigmented), a number of live and dead ants, as well as remains of vegetable material.

The living bristletails (Thysanura) were discovered in the 'Labyrinth' passages and in the 'Red Room'. Bristletails are primitive wingless insects with elongate flattened bodies, three tail-like appendages at the posterior end of the abdomen and small separate compound eyes (Delany 1954). Bristletails occur in a wide variety of habitats, ranging from houses, ant or termite nests, under stones, bark and in leaf litter, and generally feed on vegetation (Remington 1954). The specimens from Magharah Qasr Hafit appear to be adapted to a cave environment, having long antennae and lacking any pigmentation. Little scientific work has been carried out on bristletails but they regularly occur as troglobites (cave-dwellers). Although there are about 370 species recorded worldwide, it is estimated that, for example, only 60 per cent of the North American fauna is documented despite decades of intensive research. In the Arabian Peninsula, only the Lepismatidae have been examined (Irish 1991), and no work has been undertaken on other families within the Thysanura.





Clusters of small bones were found at various sites in the 'Crystal Ballroom' and 'Red Room'. These were mainly fragments of post-cranial elements of bats (Chiroptera). Two mandibles and skull (cochlea) fragments were preserved amongst the material collected. Two, and possibly three, species of bat are represented.

A mandible in 'Red Room no. 1' resembled that of the Egyptian tomb-bat *Taphozous perforatus* Geoffroy, 1818, a species distributed in west and east Africa, Egypt, south-west Arabia, Oman, Iran and north-west India (cf. Bates and Harrison 1991, 1997; Kock 1969, 1974, 1981). Other bat remains in the 'Red Room' included two skull (cochlea) fragments. Quite large, these appear to belong to a member of the Rhinolophidae (horseshoe bats).

The collection of bones from 'Red Room no. 3' included a canine tooth fragment, a small astragalus (ankle bone) plus several caudal vertebrae, these belonging to a small fox. A mandible and skull fragments of a different species of bat, as yet unidentified, were found in the 'Crystal Ballroom'.

Any of these animals may have entered the cave through small fissures and were unable to exit before they perished. Alternatively, the bats may be the residue of a more permanent roost within the cave at some time when a fissure or fissures were open to the surface.

The remains from Jebel Hafit add to knowledge of the UAE's fauna and the troglobites may be unique as the mountain and its caves have apparently constituted an environmentally-isolated niche for many millennia.

Mark Beech, Olivia Pozzan & Simon Aspinall

ACKNOWLEDGEMENTS

Tim and Pam Fogg kindly provided information about the Magharah Qasr Hafit cave system and, together with Olivia Pozzan and Simon Aspinall, collected all the faunal specimens described here. Dr John Irish (Department of Entomology, National Museum of Bloemfontein, South Africa) provided advice concerning the identification of the bristletails. David Harrison and Paul Bates (Harrison Zoological Museum, Sevenoaks, Kent, England) assisted with the identification of the bat remains.

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