Chapter 5
The Vegetation of the United Arab Emirates and Ecosystem Management Issues

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5.1 Introduction

This chapter discusses the vegetation of the terrestrial ecosystems of the United Arab Emirates (UAE). Brown and Böer (2005) gave an initial overview of the vegetation of the country, partly based on the accounts of others, most notably Roshier et al. (1996). However, that account was somewhat lacking in detail with respect to the mountains. Due to their considerable interest, a separate section covering various ecological aspects of the Hajar Mountains is given in Chap. 6.

The landscape of a large part of the UAE is dominated by low-lying, sandy desert with extensive dune systems, although salt flats (sabkha) are a highly characteristic feature in coastal areas, especially in Abu Dhabi emirate. In the east, the Hajar Mountains rise sharply above the surrounding plains. For the most part, summits are 1000 m or less, but to the north, in the Musandam peninsula, a number of peaks and plateaux exceed 1500 m and one rises to an elevation of just over 2000 m. Despite a massive increase in human activity over the past decades, natural terrestrial habitat types continue to occupy, by far, the larger part of the country, albeit often severely degraded. Characteristic anthropogenic habitat types such as oases, farmland, forestry plantations and urban areas account for a relatively small proportion of the total area.

The bi-seasonal, Mediterranean-type climate with mainly low winter rainfall and summer drought is characterized by high temperatures throughout many months of the year. In summer, daytime temperatures are normally in excess of 40 °C in the desert. Total annual mean rainfall is generally less than 100 mm in the desert

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environment, with distinctly higher amounts received in the mountains (up to about 160–190 mm). However, long-term mean values do not reflect the substantial fluctuations in rainfall amounts from one year to another, with some years experiencing virtually no or very little effective rainfall.

Potential evaporation (i.e. that water that 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. The effectiveness of precipitation is substrate-dependent. In general terms, sand sheets and dunes are much better for plant growth in arid regions than finer-grained substrates due to the 'inverse-texture effect' (Noy-Meir 1973). It is no coincidence that the most impressive stands of the UAE's national tree (*Prosopis cineraria*—or *'ghaf'*) are found on deep sands and dunes. However, sand is only a favorable medium for plant growth if it is reasonably stable (Brown and Al-Mazrooei 2003).

Vegetation is one of the defining features of many natural landscapes, including in deserts such as in the UAE. As primary producers, plants are an indispensible source of food on which all organisms ultimately depend. Herbivores are directly reliant on plants; carnivores indirectly so in that they often prey on herbivores. Apart from sabkha, which typically does not support plant growth (except on its margins—Brown (2006)), the majority of major habitat types in the UAE are characterized by one or several plant communities. However, vegetation cover in terrestrial desert habitats is generally sparse and often patchy, and this is especially the case in western and southern regions that receive less rainfall than in other parts of the country. Given the extreme climatic and other environmental parameters, vegetation cover is highly sensitive to overgrazing, and this has led to a severe reduction of it in many locations. In addition, the floristic composition has become depauperate, with species intolerant of high grazing pressures disappearing.

In the following, an account is given of characteristic plant communities according to broad habitat type in which they typically occur. In desert areas, communities are usually referred to after the dominant perennial species and sometimes co-dominant species present (Brown and Mies 2012). It is important to understand that the current vegetation characteristics reflect a snapshot in time, and that even several decades ago, vegetation cover may have looked quite different in some areas. Vegetation degradation, which has led to profound changes in cover and floristic attributes, has proceeded rapidly in many parts of the country, as explained below.

Given the lack of English common names for most plant species of the Emirates, the scientific nomenclature used here follows that of Jongbloed et al. (2003) to allow non-specialist readers the opportunity to check plants in that widely-used book. In the meantime, there have been considerable nomenclatural changes, but not all of them are likely to remain 'valid' for any length of time (see also Chap. 13).

5.2 Broad Terrestrial Habitat Types and Their Vegetation

5.2.1 Coastal Zone

The coastline of mainland UAE extends for about 650 km. It comprises the Arabian Gulf coast to the west of the Hajar Mountains and the Indian Ocean (Gulf of Oman) coast to the east. The Arabian Gulf coastline is predominantly flat, with warm, shallow waters. Numerous inlets and lagoons ('*khors*') have served historically as harbours for fishing, trading and pearling.

When compared to many terrestrial habitats, the coastal vegetation of the UAE and adjacent countries with comparable climates is often species-poor. In some cases, the stands are virtually monospecific, but they can be highly productive nonetheless, and often much more so than the inland vegetation types (Deil 1998; Brown et al. 2008). Furthermore, coastal vegetation often occurs as distinct belts that run more-or-less parallel to the coast, indicating the overriding influence of the sea in affecting species composition. With increasing distance from the coastline, the influence of salinity often, but by no means always, diminishes. Within coastal vegetation belts, abrupt changes in key abiotic factors are reflected in corresponding changes in the vegetation cover. This can lead locally to the development of specialised habitats and the formation of small-scale vegetation mosaics (Deil 1998).

5.2.1.1 Mangroves

Mangroves can be regarded as a woodland formation below the high-tide mark (Walsh 1974). They are generally typical of tropical areas where summer temperatures are not too extreme. Along the Arabian Gulf coast, mangroves are found mainly east of Jebel Dhanna (Böer and Aspinall 2005; Saenger et al. 2004). They are particularly well-developed in the vicinity of Abu Dhabi Island and Umm Al-Quwain, continuing north-eastwards into Ras Al Khaimah, but are absent from the Musandam due to the steep rocky shoreline there. Mangroves are also found at Khor Kalba on the Indian Ocean coast, where the extensive and venerable stand continues into Oman (see Chap. 7).

Mangroves have been, and continue to be, planted in various locations along the coastline, and separating natural stands from artificial ones is not straightforward. It is also probably the case that some planted stands occur in sites that were once home to natural mangrove forests or woodlands, and which were cut down for economic purposes at some time in the distant past.

Mangroves occupy the transitional zone between the open sea and the often rather sparsely vegetated coastal plain. They are usually found growing on fine-grained substrates in bays and inlets where they are protected from wave action. This allows the seedlings to become rapidly established in such situations.

Probably due to the harsh summer climate throughout most of the region, only one species of mangrove, *Avicennia marina*, is able to thrive naturally, although it

has been speculated that in historical times, a second species, *Rhizophora mucronata*, might have occurred in some areas (Saenger et al. 2004). In addition, due to the extreme climatic conditions and the high salinity of the Arabian Gulf waters, the *Avicennia* trees rarely exceed 3–4 m in height (Saenger et al. 2004). However, the stands are much denser than all other terrestrial vegetation types in the country.

The accompanying vegetation is almost invariably very poor in species. A regular associate in the UAE is the halophytic (i.e. associated with saline environments) dwarf shrub *Arthrocnemum macrostachyum*, which, however, occupies only the uppermost intertidal zone. Cover values of this chenopod (former member of the goosefoot family, Chenopodiaceae, now Amaranthaceae) vary from 0 to ca. 80%.

5.2.1.2 Saltmarsh Vegetation

In the following, the main saltmarsh plant assemblages are described. These are communities that are inundated by seawater for substantial periods of time, usually at high tides, and where the coastal mud is exposed at low tide. Saltmarsh vegetation is characterized floristically to a large extent by chenopods, and most species, especially the dominants, are perennial dwarf shrubs (Brown et al. 2008). Notable exceptions include the annual chenopods *Salicornia sinus-persica* (Fig. 5.1), *Bienertia cycloptera* and *Suaeda aegyptiaca*. Locally, the rush *Juncus rigidus* predominates.

Fig. 5.1 *Salicornia sinus-persica*, a local annual chenopod (now Amaranthaceae) that was formerly assumed to be *S. europaea*. Photo credit: Gary Brown

Arthrocnemum macrostachyum forms a highly characteristic, almost monospecific salt-marsh community that can cover quite large expanses of both the Arabian Gulf and Indian Ocean coasts of the UAE. In contrast to the morphologically similar *Halocnemum strobilaceum*, *Arthrocnemum* is also associated with mangroves. It would appear that the community is best developed in muddy, sheltered locations with little wave impact, as has been described for various countries in the region, including for the UAE (Brown et al. 2008). Over the past two decades, several large areas of *Arthrocnemum* coastal marshland have been lost to coastal development. For example, a large patch has been destroyed on the east coast of the UAE just north of Fujairah city where *Limonium axillare* was present in the less-frequently inundated sites.

The *Salicornia sinus-persica* community has a distinctly patchy and very localised distribution in the UAE, as indeed is the case along the entire coastline of the east of the Arabian Peninsula. Our own observations suggest that it is present mainly in large, sheltered bays where migratory seabirds accumulate in large numbers. In the UAE, it is predominantly found in the bay complexes near Umm Al Quwain and at Al Rams. Because *S. sinus-persica* is an annual species, it is only visible at certain times of the year.

The large rush *Juncus rigidus* is a species of poorly drained, saline ground in a few coastal locations in the UAE. It reportedly previously occurred in the vicinity of Abu Dhabi Island (Jongbloed et al. 2003), but now it seems to be restricted to a localized coastal area at Al Rams in Ras Al-Khaimah, which is associated with freshwater springs. Here it forms extensive stands that are gradually being lost due to urban encroachment (Fig. 5.2). The stands are therefore of very high conservation value.

5.2.1.3 Vegetation of the Coastal Plains

Low relief is a prominent feature of large sections of the Arabian Gulf coastline in the UAE. As a consequence, coastal plains of varying size occur in many areas. Coastal plains are regarded as flat expanses in close proximity to the coast where soil salinity exerts at least some influence on species composition. The substrate of these plains varies according to geographical location and the associated soil conditions, which range from rock, gravel, silt, silty sand to sand. The plant assemblages usually have the mild to moderately halophytic dwarf shrub *Zygophyllum qatarense* as a prominent constituent. Its cover can vary from nearly zero to in excess of 75% in particularly favourable locations. The species is usually absent where persistent highly saline conditions occur.

In contrast to some adjacent regions, the *Zygophyllum* community is rather species-poor in the UAE, probably due to climatic constraints. One of the more frequent associates is *Suaeda vermiculata*, which also occurs on disturbed, damp ground near the coast. In addition, *Zygophyllum* is often accompanied by ecotypes of the widespread tussocky sedge *Cyperus conglomeratus*, and in drier conditions, locally by the dwarf shrub *Echiochilon jugatum*. *Lycium shawii* is a widespread

Fig. 5.2 The stands with *Juncus rigidus* at Rams are of very high conservation value. Photo credit: Gary Brown

shrub of this community in the adjacent parts of Saudi Arabia and Qatar, but this does not appear to be the case in the UAE. Where elevated soil-salinity is prevalent, species such as *Salsola cyclophylla*, a rather non-descript dwarf shrub, and the perennial grass *Sporobolus ioclados* can occur locally.

5.2.1.4 Coastal Sand Sheets and Dunes

Vesey-Fitzgerald (1957) coined the term 'coastal white sand associations' to describe the vegetation of the predominantly calcareous sands that run parallel to much of the western and southern Arabian Gulf coastline, including that of the UAE. Coastal sands are derived almost exclusively from marine organisms and carbonate sediments, and therefore consist to a large extent of calcium carbonate ($CaCO_3$). In contrast, the inland desert sands are composed predominantly of quartz grains. As indicated by the observations of Vesey-Fitzgerald (1957), the coastal white sand vegetation is frequently set back somewhat from the immediate coastline, although this is not necessarily always the case.

A striking feature of the coastal white sands in many areas is the apparent lack of any direct influence of salt, despite the sometimes immediate proximity to the sea; in some cases within as little as 10 m. This is only possible where the land lies well above the high-tide mark, i.e. at least 2 to 3 m higher. In such cases, the vegetation is

Fig. 5.3 Coastal white sand vegetation near Jebel Ali. This vegetation type, characterized physiognomically by a sparse cover of perennial dwarf shrubs (here mainly *Sphaerocoma aucheri*) and grasses, is of outstanding conservation concern. In wet winters, carpets of annuals may appear. Photo credit: Gary Brown

characterized almost exclusively by glycophytes, i.e. non-halophytic species (Brown and Böer 2005).

In general terms, the vegetation of the coastal white sands is characterized physiognomically by a sparse cover of perennial dwarf shrubs and grasses (Fig. 5.3). Vegetation cover of the perennials rarely exceeds 3–5% in the UAE.

Mainly to the north-east of Abu Dhabi Island (but also probably in fragments further to the west) extending to the Musandam, the coastal white sand vegetation contains a number of highly characteristic perennials, including the perennial grass *Panicum turgidum*. Deil and Müller-Hohenstein (1996) gave the first more comprehensive insight into the coastal white sand vegetation in the UAE, and Brown et al. (2007) described the stands at Taweela, east of Abu Dhabi Island. The coastal white sand vegetation at Taweela has since been largely destroyed due to development. Characteristic species are the dwarf shrubs *Sphaerocoma aucheri* and *Cornulaca monacantha*. Other dwarf shrubs that are regular associates include *Helianthemum lippii* and *Heliotropium kotschyi*. The most widespread perennial grass is *Coelachyrum piercii*, which, along the Arabian Gulf coast of the UAE, appears to be restricted to the stretch between Taweela and the Musandam. It is highly characteristic of the coastal white sands, but it also grows as a ruderal by roads in Dubai and, in the north-east of the UAE, it occurs up to several kilometres inland on red sands. The tussock grass *Pennisetum divisum* is also occasionally present. The sedge *Cyperus arenarius* is usually widespread and abundant.

These and other perennials are accompanied by a profusion of annuals, particularly in wet years, including *Arnebia hispidissima, Herniaria hemistemon, Hippocrepis areolata, Launaea mucronata* and *Lotus halophilus*.

On more saline sands, species richness is much lower, and *Panicum turgidum* is generally absent, as are *Sphaerocoma* and *Coelachyrum.* Instead, the slightly to moderately salt-tolerant *Sporobolus ioclados* and *Zygophyllum qatarense* can be locally common and widespread. In addition, perennial dwarf shrubs such as *Heliotropium kotschyi* and *Salsola drummondii* appear in varying degrees of abundance.

Coastal white sands are perhaps one of the most threatened habitat types regionally, much more so than the more high-profile but more plant species-poor mangrove forests (see Brown et al. 2007). In fact they were already listed by Brown and Böer (2004/2005) as a habitat type of major conservation importance.

5.2.1.5 Vegetation of Some Islands

The UAE possesses at least 200 islands, most of which are rather small and flat, primarily occurring in the southern Gulf basin in Abu Dhabi. However, some islands can be relatively high, attaining elevations well in excess of 100 m. Such higher islands are invariably salt domes.

Zirku is a typical salt dome island that covers an area of 7.8 km^2. It is characterized by a largely flat coastline, a wide coastal plain and hills in the interior that are dissected by wadis. Perennial vegetation cover is extremely sparse on the slopes, typically well below 2%. However, in more favourable years, cover increases markedly, but probably not more than about 5%. The annual herb *Zygophyllum simplex* and the chenopod *Salsola imbricata* are the two most conspicuous species. The trailing caper *Capparis spinosa* is also fairly widely distributed on the rocky slopes. Short-lived plant species such as *Forsskaolea tenacissima* and *Mesembryanthemum nodiflorum* presumably occur where moisture is temporarily available.

The wadis undoubtedly have the highest diversity of plant species in the interior of the island, and species recorded include *Aizoon canariense*, *Cenchrus ciliaris*, *Emex spinosa*, *Lotononis platycarpa*, *Salsola imbricata* and *Zygophyllum simplex* (Brown 2008).

Locally, the beach vegetation just above the high tide mark comprises *Halopyrum mucronatum*, *Salsola imbricata* and *Sphaerocoma aucheri*.

In contrast to salt dome islands, other islands such as Marawah are flat and generally featureless. Some areas of Marawah are occupied by sabkha that is lacking in vegetation cover (see below), but where sand overlies the sabkha and also on more rocky substrates, plants can be quite conspicuous. Species present include *Anabasis setifera*, *Halopeplis perfoliata*, *Limonium axillare*, *Salsola imbricata*, *Seidlitzia rosmarinus* and *Suaeda vermiculata*. Quite extensive stands of mangroves (*A. marina*) occur predominantly on the sheltered side of Marawah, i.e. facing towards the mainland, but also locally elsewhere, including in the north-west.

5.2.1.6 Sabkha Vegetation

Sabkha refers to salt-encrusted, flat desert. It constitutes an extremely inhospitable environment due to the high temperatures, exposure to severe wind erosion, and in particular, the hypersaline substrate (see Fig. 2.20, Chap. 2). Depending on its location, but also its genesis, a broad distinction can be made between coastal and inland sabkha. Coastal sabkha is a major landscape feature in Abu Dhabi emirate, occasionally extending far inland where it can intergrade with inland sabkha. It lies close to the high intertidal, usually less than a few metres above, or even below the high-tide level in places. After heavy rainfall or severe northerly coastal storms in association with high tides, parts of the sabkha may become immersed for up to several weeks (see Fig. 2.18, Chap. 2). Even after the flooding has receded, the surface usually remains slightly moist due to several factors, most importantly the capillary action from the underlying water table and the highly hygroscopic nature of the surface salts. The surface crust can absorb moisture not only from below, but also from the air, even at low relative humidity.

Sabkha proper is typically devoid of vascular plant species (Brown et al. 2008). Plant life is mainly restricted to the margins or where there is a veneer of wind-blown sand overlying the highly saline surface. Various members of the Chenopodiaceae (now Amaranthaceae) are best represented in terms of species number, but the Zygophyllaceae also play a prominent role in the vegetation cover. Halophytes inevitably predominate, ranging from mildly halophytic species such as *Zygophyllum qatarense* to the succulent *Halopeplis perfoliata*, which, along with *Halocnemum strobilaceum*, is one of the most salt-tolerant species in the Arabian Peninsula. In fact one of the most widespread communities occurring on sabkha is dominated by *Halocnemum strobilaceum*, with the woody succulent *Halopeplis perfoliata* also occurring in small stands locally. Where the overlying sand layer is thicker on the sabkha surface, i.e. more than 30 cm above the capillary fringe, non-halophytic vegetation gradually gains a foothold.

Zygophyllum qatarense is one of the more widespread and common species on sabkha, both coastal and inland, where the salinity is not so pronounced due to the presence of an overlying sand layer. This is typically wind-blown coastal sand and may contain a significant fraction of shells and corals in some locations. *Zygophyllum* plants may appear dead, often for substantial periods of time (possibly years), only to become green and physiologically active again when the conditions are more amenable, usually after heavy rainfall.

Other chenopods associated with the margins of sabkha include *Atriplex leucoclada*, *Bienertia cycloptera*, *Salsola imbricata*, *Seidlitzia rosmarinus*, *Suaeda aegyptiaca* and *Suaeda vermiculata*. The chenopod *Anabasis setifera* is a characteristic pioneer species of reclaimed sabkha in coastal areas, for instance near Abu Dhabi Island.

Extensive inland salt flats, often referred to as ‘inland sabkha’, are found in various parts of Abu Dhabi emirate. Sabkha Matti, located in the far west of the emirate, is the largest of these, but impressive salt flats also occur among the high

dunes in the south and east, particularly in the Al Khatam, Umm Al Zumul and Liwa areas, where they are developed on interdunal plains (see Chap. 2). These areas of sabkha are flooded after heavy rainfall, and temporary lakes may persist for several weeks (see Chap. 2).

Halophytic species found on inland sabkha include the widespread *Zygophyllum qatarense*, *Seidlitzia rosmarinus* (e.g. in the Liwa area of southern Abu Dhabi emirate), *Halopeplis perfoliata* (very local away from the coast, e.g. in the Liwa), *Suaeda aegyptiaca* (usually in more disturbed locations) and *Limonium axillare* (generally very rare inland).

5.2.1.7 Vegetation of Tertiary Mesas Associated with Sabkha

A characteristic feature of many areas of coastal sabkha are low, rocky hills of flat-lying Tertiary sedimentary rocks (mesas), which relieve the monotony of the landscape. Depending on the influence of salt-laden dust, these rock exposures are colonised by a mix of halophytic and non-halophytic species (Brown 2006). Salinity is presumably introduced by wind-blown saline dust from the surrounding sabkha. Halophytes found in such locations in the Western Region of Abu Dhabi include *Anabasis setifera*, *Seidlitzia rosmarinus* and *Salsola* spp., such as *S. drummondii*, which can be dominant locally. The mesas act as 'refugia' for glycophytes, which typically do not grow on the surrounding sabkha. These plants exploit small accumulations of soil behind rocks or in gullies on the smaller jebels. On the flat tops of larger mesas, the influence of salt appears to be diminished, and so glycophytes can cover larger areas. Among the plant species present are a number of desert annuals, such as *Arnebia hispidissima* and *Savignya parviflora*. *Dipcadi erythraeum* is a characteristic lily-like plant that can occur in large populations locally on some jebels after heavy rainfall. *Calligonum comosum*, *Cornulaca monacantha*, *Helianthemum lippii*, *Indigofera* spp., *Panicum turgidum* and *Pennisetum divisum* are some of the characteristic perennials found on the plateaux of larger jebels.

Tertiary jebels are also found locally far inland, such as in Al Khatam to the south-west of Al Ain in Abu Dhabi emirate, and inland of Ras Al Aysh and the Shuweihat peninsula in the Baynouna area of western Abu Dhabi, but these tend to be largely devoid of plants.

5.2.2 Vegetation of the Inland Deserts

The following section deals with the vegetation of the inland deserts. As a convenient, albeit often imprecise differentiation, the sand sheets and sand dunes can be separated from the plains (alluvial and interdunal, which themselves can be sandy).

Sand seas occupy a significant part of the country and consist of extensive sand dune systems and deeper sand sheets (see Figs. 2.5, 2.7, 2.8, 2.9, 2.11 and also

Fig. 5.4 Megadunes, i.e. dunes taller than 20 m, are characteristic of the far south of the UAE. Photo credit: Gary Brown

Chap. 2). Sandy habitats vary in the degree of substrate mobility, depending on location and the specific situation, even within small geographical areas. This has important repercussions for plant colonisation: stable sand sheets are generally favourable for plant establishment, whereas mobile sandy substrates are at best colonised by a few specialist species. As a consequence, it is usually the case that the dune hollows have the highest cover, also due to the more favourable water availability for shallow-rooting plants. Megadunes, i.e. dunes taller than 20 m, are characteristic of the far south of the UAE (Figs. 5.4). Particularly in western parts of the country, aeolianite, i.e. cemented dune sand, is a widespread feature (see Fig. 5.11 below).

Plains of various soil types occur throughout the UAE. They are generally regarded as more-or-less flat or rugged expanses of land away from the major sand seas and mountains. Plains in the vicinity of the mountains are typically alluvial (i.e. erosion deposits), with interdunal plains associated with the sand seas. In some cases, rocky sections or areas of exposed caliche (‘*gatch*’—i.e. a relatively thin, but solid crust of soil or sediment that has been cemented together by the precipitation of calcium carbonate, gypsum or other minerals) occur on the plains.

In the following, the vegetation formations are arranged according to main growth form present, beginning with the trees, followed by shrubs, dwarf shrubs and others.

5.2.2.1 *Prosopis cineraria* Community

The tree *Prosopis cineraria* (‘*ghaf*’) is a characteristic species of the eastern part of the UAE. It has been named the national tree of the UAE due to its considerable cultural and ecological significance. It provides shade and shelter for native fauna and domestic livestock, and it is used as an important source of forage. It occurs in four distinct habitat types (1) on dunes, (2) very locally (in Ras Al Khaimah) on interdunal sand sheets, (3) on alluvial plains, but mainly to the east of the Hajar Mountains, and (4) in mountain wadis. However, it is only on the dunes and sand sheets that it predominates and forms a distinctive community. Although the four habitat types are markedly different, one common feature is that large amounts of water are stored in the substrate, allowing *Prosopis* to thrive.

The remaining *Prosopis* stands are most probably remnants of former, more extensive woodlands and forests that have gradually disappeared with the aridification of the climate over the past several thousand years. Anthropogenic causes may have accelerated the decline in more recent times.

Prosopis cineraria often forms small groves (i.e. clusters of trees—Fig. 5.5) or extensive parkland. ‘Parkland’ refers to individual or small groups of trees scattered over large areas. *Prosopis* groves are typically developed on dunes that can attain heights well in excess of 10 m. The extensive rooting system of the tree is key to its survival in such situations. Perhaps the best existing stands in the region are developed 5 to 40 km inland from the coast, extending from the eastern part of Dubai emirate through Umm Al Quwain and Sharjah into Ras Al Khaimah. However, smaller well-developed stands also occur much further inland, such as in the vicinity of Al Ain. In addition, some stands are found on high dunes (10–20 m high) in immediate proximity to the sheltered coastline to the south-west of Ras Al Khaimah city. The sand there is red rather than white, indicating a non-marine origin and the lack of influence of salinity.

Fig. 5.5 A grove of *Prosopis cineraria* with the sedge *Cyperus conglomeratus* in the foreground at Ghaf Nazwa (Dubai). Photo credit: Gary Brown

Lycium shawii is often encountered in the stands, although nearly always heavily browsed due to the high grazing pressure from camels. *Haloxylon salicornicum* is frequently present, at least locally.

The stands in the north-east of the UAE display, by far, the richest annual flora in the country with respect to the desert areas. Characteristic species include, among many others, *Asphodelus tenuifolius*, *Emex spinosa*, *Eremobium aegyptiacum*, *Gisekia pharnaceoides*, *Launaea capitata*, *Lotus halophilus*, *Plantago boissieri*, *Schismus barbatus* and *Tragus racemosus*. *Malva parviflora* is often abundant, and a sure indicator of overgrazing. The same applies to a lesser extent to *Aizoon canariense* and *Plantago ovata*.

Elsewhere in the UAE, the stands are generally poorer in annuals, although species such as *Astragalus hauarensis* sometimes occur (e.g. near Al Faqa).

5.2.2.2 *Acacia tortilis* Parkland on the Alluvial Plains Associated with the Hajar Mountains

In the UAE, *Acacia tortilis* is mainly restricted to the north-east of the country where it is often the physiognomically most conspicuous, but not necessarily dominant species. As a general rule of thumb, the species occurs east of the Dubai-Al Ain highway, although a few trees make it slightly further west, and also in the vicinity of Al Ain. In addition, there are a few scattered individuals on the Sila'a Peninsula in the far north-west of the country.

The *Acacia tortilis* stands on the alluvial plains associated with the Hajar Mountains are quite extensive (Fig. 5.6). Typical perennial associates include *Lycium shawii*, *Haloxylon salicornicum* and *Rhazya stricta*, and occasionally the shrub *Acacia ehrenbergiana*. The last species also occurs on some interdunal plains to the west of any *A. tortilis* stands (e.g. Umm Al Zumul, Al Marmoum Desert Conservation Reserve and near Sweihan).

5.2.2.3 *Haloxylon persicum* Community

In the UAE, the shrub *Haloxylon persicum* (Arabic: *'ghada'*) is highly characteristic of a narrow belt extending some 75 km from Al Wathba, roughly to the south of Abu Dhabi Island, south-westwards towards, but not reaching Medinat Al-Zayed. This UAE population represents an eastern outlier of the Rub Al Khali 'islands' of the species, which are otherwise found in Saudi Arabia.

The typical environmental setting of the open shrublands comprises low dunes and deep sand sheets. The shrub forms a species-poor plant assemblage in which *Haloxylon salicornicum* can be co-dominant, at least locally (Fig. 5.7). It should be noted that although it is sometimes referred to as 'saltbush vegetation', *Haloxylon persicum* vegetation is not a halophytic type, nor is it even characteristic in Arabia of sabkha margins.

Fig. 5.6 *Acacia tortilis* parkland on the alluvial plains near Dibba (Fujairah). Photo credit: Gary Brown

Fig. 5.7 *Haloxylon persicum* stands in the Al Ghada Protected Area (Abu Dhabi). Photo credit: Gary Brown

Frequent fog in the areas of occurrence of *H. persicum* enables the growth of crustose lichens (e.g. *Arthonia* sp., *Caloplaca* sp. on the bark of the shrubs (Brown 2005). Aspinall and Hellyer (2003) refer to the stands in the UAE as a 'dew-forest', which is not strictly accurate as *H. persicum* is a shrub, rather than a tree, and forest implies at least fairly dense vegetation cover, which is not the case. Although the stands occur in an area of high humidity, this is unlikely to be a major determining environmental factor given the much drier climatic conditions in other parts of the regional range of the species.

The *Haloxylon persicum* shrublands in the UAE are of outstanding conservation value.

5.2.2.4 *Calligonum* Communities

Calligonum comosum was probably a widespread species of low desert dunes and sand sheets throughout much of the region, absent from parts of the Rub Al Khali where it is replaced by the endemic and morphologically similar *Calligonum crinitum*. However, the species has suffered substantially from massive overgrazing by domestic livestock over the past decades, which has led to a marked decline in its abundance. On the dunes in the east of the UAE, where *C. crinitum* does not occur, stands with *C. comosum* as the main woody species are developed extremely locally. This is especially the case where the species is protected from grazing by domestic livestock. For example, the species has begun making an impressive return after camels were removed from the Dubai Desert Conservation Reserve (DDCR—Fig. 5.8) and the same phenomenon was recently observed by us in the Al Houbara Protected Area in Abu Dhabi.

Calligonum crinitum is a species endemic to the Arabian Peninsula and in the UAE appears to be restricted primarily to the elevated dune areas in the southern half of the country, although also found on lower dunes closer to the coast in the west. The shrub forms a very open, species-poor community. Typical accompanying species include *Cyperus conglomeratus* and *Limeum arabicum*.

5.2.2.5 *Leptadenia pyrotechnica* Community

Leptadenia pyrotechnica is a virtually leafless shrub that has a wide natural distribution, ranging from Senegal in West Africa eastwards through Arabia into western India.

In the UAE, the species is absent or very rare in the western half of the country, but it becomes increasingly prevalent east of Abu Dhabi Island. To the west of the Hajar Mountains, it forms a distinct shrub community on low dunes, mainly in Dubai, Sharjah, Umm Al Quwain and Ras Al Khaimah. However, *Leptadenia* is absent from the plains to the east of the Hajar Mountains in the UAE.

The community is characterized by a well-developed ground layer of perennials, often woody-based, consisting mainly of *Dipterygium glaucum*, *Indigofera colutea*,

Fig. 5.8 *Calligonum comosum* is making a comeback in areas where it has been protected from grazing by domestic livestock, such as here in Dubai Desert Conservation Reserve. Photo credit: Gary Brown

I. intricata, *Limeum arabicum* and *Tribulus arabicus*, occasionally also *Calligonum comosum*. Common annuals include *Arnebia hispidissima*, *Eremobium aegyptiacum* and *Neurada procumbens*, as well as the rather delicate, short-lived perennial *Monsonia nivea*.

5.2.2.6 *Calotropis procera* Community

As a species, *Calotropis* is found throughout many parts of the Arabian Peninsula, where it is usually regarded as a sure indicator of disturbance or overgrazing because it is a toxic plant that is one of the few species remaining in heavily denuded areas. For instance, in the west of the UAE, it is often restricted to urban or agricultural environments. Extensive stands on low dunes and extensive sand sheets characterized by the dominance of *Calotropis procera* are found in the same broad geographical location as the *Leptadenia* community in the east of the UAE. In fact such *Calotropis* stands often represent a highly degraded, species-poor stage of the *Leptadenia* community. Two regular associates are the perennial prostrate vine *Citrullus colocynthis* and the sedge *Cyperus conglomeratus*.

Apart from on dunes, the typical species assemblage also dominates in some sandy wadis away from the mountains where there is occasional inundation. For instance, extensive stands occur in Wadi Faya (Sharjah emirate—Fig. 5.9) and in Wadi Lamhah, on the Umm Al Quwain-Ras Al Khaimah border.

Fig. 5.9 Extensive stand of *Calotropis procera* in Wadi Faya (Sharjah). Photo credit: Gary Brown

5.2.2.7 *Cornulaca arabica* Community

Cornulaca arabica is an endemic dwarf shrub that according to Mandaville (1990) dominates extensive tracts of the high dunes of the Rub Al Khali in Saudi Arabia. It also occurs in the far south of Abu Dhabi emirate and although it inhabits the higher dunes (Fig. 5.10), it is also found on the lower slipfaces. Typical associates include *Cyperus conglomeratus*, locally *Limeum arabicum* and, to a lesser extent, *Tribulus arabicus* agg.

5.2.2.8 *Haloxylon salicornicum* Community

Haloxylon salicornicum is a species that thrives on sand sheets and low dunes as well as on gravelly near-coastal plains in the country. In fact it could well be the case that the occurrence on plains is due to sand deflation associated with landscape degradation, at least in some locations.

In the north-east of the UAE, for instance on the mainly red sands of Sharjah emirate, the northern part of Ras Al Khaimah and locally in the east of Dubai emirate, the *Haloxylon salicornicum* stands can be quite species-rich in terms of accompanying desert annuals.

In the north-west of the country, species-poor *Haloxylon salicornicum* stands predominate locally on sand sheets and low dunes, for instance in the Al Houbara Protected Area, where grazing by domestic livestock has ceased (Fig. 5.11).

Fig. 5.10 The endemic dwarf shrub *Cornulaca arabica* on dunes in the Liwa. Photo credit: Gary Brown

Perennial associates in the Western Region of Abu Dhabi include *Dipterygium glaucum*, *Fagonia ovalifolia*, *Heliotropium kotschyi*, *Monsonia nivea*, *Polycarpaea repens* and *Zygophyllum qatarense*. On sandier substrates, species such as *Limeum arabicum* occur.

However, the stands in the UAE are generally much poorer in accompanying desert annuals when compared to the north-eastern part of the Arabian Peninsula (see Brown 2003).

The Desert Hyacinth, *Cistanche tubulosa*, is a frequent root parasite on *Haloxylon salicornicum* throughout many parts of the UAE.

Typical micro-nebkhas (mounds of wind-blown sand) are often formed at the base of the plants, which, depending on their stability, can provide an important habitat for burrowing faunal species (see Fig. 5.11). In some cases, true nebkhas, mounds of sand generally taller than 1 m, can be observed, as for instance in the Yaw Al Debsa Protected Area (Fig. 5.12).

5.2.2.9 *Zygophyllum qatarense* Community

The highly variable dwarf shrub *Zygophyllum qatarense* is a typical species of mildly to moderately saline habitats near the coast, but also in the desert interior. Inland, it forms a distinct community on low to medium dunes (Fig. 5.13). As a rough guide, the inland community is found to the south-west of the Dubai–Al Ain

Fig. 5.11 *Haloxylon salicornicum* community on slightly mobile sand sheets in Abu Dhabi emirate. Micro-nebkhas are clearly visible as lighter coloured mounds of sand at the base and in the lee of the individual dwarf shrubs. Extensive patches of aeolianite, i.e. lithified dune sand, are visible in the foreground. Photo credit: Gary Brown

Fig. 5.12 True nebkhas supporting many *Haloxylon salicornicum* individuals in the Yaw Al Debsa Protected Area (Abu Dhabi). Photo credit: Gary Brown

Fig. 5.13 Species-poor *Zygophyllum qatarense* vegetation on low dunes in the Al Marmoum Desert Conservation Reserve (Dubai). Photo credit: Gary Brown

road and extending throughout large sections of the western part of the UAE. Cover of *Zygophyllum* can be quite high—up to about 3% in places. However, the accompanying vegetation is largely restricted to *Cyperus conglomeratus*. Annuals appear to be extremely scant in this community.

Zygophyllum qatarense is also a common and widespread species on interdunal plains with slightly to moderately saline soils, where it can form extensive stands. The species is often developed best towards the margins of the plains where there is a thin veneer of sand from the adjacent dunes covering the surface, or on sand sheets that are developed towards the centre of wider plains. Typical associates include *Fagonia ovalifolia* and *Monsonia nivea* as well as desert annuals such as *Neurada procumbens*, *Savignya parviflora* and *Zygophyllum simplex*.

5.2.2.10 Vegetation Types with *Rhanterium epapposum*

Satchell (1978) reported that the composite *Rhanterium epapposum* was once found on the alluvial plains to the west of the Hajar Mountains, apparently where sand overlies mainly limestone rock. This is presumably in the vicinity of the foreland ridges such as Jebels Buhais and Faya (see below). It was also common as part of a 'wooded plain community' *with Prosopis cineraria* and *Lycium shawii* on the Jiri Plain (i.e. on alluvial plains in the north-east of the UAE, north of Idhan (= Adhan)). Currently, it appears that *Rhanterium* has now completely disappeared from the

plains except in areas that are protected from grazing in some form or another, where the species remains rather sparse.

It should also be noted that the *Rhanterium* community was also once fairly widespread on sand sheets in the vicinity of Dubai as recently as 1987, especially in the transition zone between coastal white sands and inland red sands (Deil and Müller-Hohenstein 1996). These stands have now all but disappeared, largely due to urbanisation, but possibly also on account of overgrazing. A small remnant of this vegetation persists in the Al Marmoum Desert Conservation Reserve (Fig. 5.14).

Small *Rhanterium* plants can be found by roadsides in the north-east of the UAE, i.e. in sites that domestic livestock cannot reach, for example to the south-east of Dubai. Such observations give some insight into the former distribution of the species.

5.2.2.11 *Rhazya stricta*-Dominated Stands

The woody-based perennial herb *Rhazya stricta* is a common species on the alluvial plains in the east of the UAE extending into Oman. It is avoided by livestock due to its reputed toxicity and as a consequence, it can become dominant locally on silty gravel plains.

Fig. 5.14 Small patch of *Rhanterium epapposum* dwarf shrub vegetation in the Al Marmoum Desert Conservation Reserve (Dubai). Photo credit: Gary Brown

5.2.2.12 Vegetation Types with *Fagonia ovalifolia*

Apart from *Zygophyllum qatarense*, which was dealt with above, the woody-based perennial herb *Fagonia ovalifolia* can predominate on some interdunal plains, mainly in the northern half of the country, in addition to alluvial plains associated with the Hajar Mountains. As with *Zygophyllum*, this species requires heavy rainfall to develop leaves and become physiologically active, otherwise it appears distinctly 'dead'. Mixed stands of *Zygophyllum qatarense* and *Fagonia ovalifolia* are frequently observed on interdunal plains in some parts of the UAE.

5.2.2.13 *Tribulus-Dipterygium-Limeum* Community

This community is composed primarily of various dwarf shrubs and woody-based herbs, notably *Tribulus arabicus* agg., *Dipterygium glaucum* and *Limeum arabicum*. *Cyperus conglomeratus* is also a widespread associate. The community is found in various parts of the UAE. Depending on the location, it can also contain a variety of other perennials, especially *Indigofera* spp. (e.g. *Indigofera intricata* and *I. colutea*). In the climatically more extreme parts of the UAE, i.e. in the Rub Al Khali, the community is species-poor and comprises mainly *Tribulus arabicus* agg., *Cyperus conglomeratus* and *Limeum arabicum*. Towards the coast, *Dipterygium glaucum* is often more characteristic. In addition, various desert annuals become locally abundant, especially in the north-east.

5.2.2.14 *Cyperus conglomeratus* Community

Away from the mountains, *Cyperus conglomeratus* is a widespread species found throughout the region, often on deeper sands (see Fig. 13.5 and also Fig. 13.12 Chap. 13). The species may be the only perennial present in large sections of the sand seas. It is particularly well adapted to such environments, as highlighted in Chap. 13. Vegetation cover is often extremely low.

5.2.2.15 *Panicum turgidum* Community

Extensive inland sand sheets with perennial grass vegetation dominated by *Panicum turgidum* are found in the north of the Al Marmoum Desert Conservation Reserve (Dubai emirate). Accompanying perennial grasses include *Pennisetum divisum*, *Stipagrostis plumosa* and *S. uniplumis*. The last species is distinctly rare and localized in the UAE. It is interesting to note that *Cyperus conglomeratus* is uncommon in this community, and yet there is a rather abrupt transition to *Cyperus*-dominated vegetation in Al Marmoum, largely without the aforementioned perennial grasses, that remains unexplained.

Perennial vegetation cover can be remarkably high—in excess of 15% in some cases. This habitat type is of exceptional conservation value, as it appears to be largely restricted to Dubai in the country, where it has probably been disappearing at an alarming rate over the past decades. Our observations have shown it to be a key habitat for the remarkable Persian Wonder Gecko (*Teratoscincus keyserlingii*).

5.2.3 Vegetation of the Hajar Mountains

The Hajar Mountains in the UAE comprise three ecologically distinct sections: the main Hajar range, the Ru′us Al Jibal (Musandam) and the Foreland Ridges. Only a small part of the Ru′us Al Jibal lies within the UAE, the largest portion belonging to Oman.

Elevation, geology and substrate interacting in response to the local environmental conditions contribute to a surprisingly varied vegetation cover in the mountains. Describing the variety of plant assemblages and making relevant generalisations is not an easy task due to the lack of exhaustive field studies undertaken to date, the relatively sparse vegetation cover and the absence of clear plant indicators. Furthermore, associating plant communities with specific elevational belts is problematic because in some cases, changes in vegetation cover vary quite markedly in different areas of the mountains depending on geographic location, underlying bedrock, substrate type, aspect and other environmental factors. A prominent feature of the Hajar Mountains is the intricate network of wadi systems, and a few characteristic species are given in a separate section below. Most gullies and wadis do not carry flowing water, but nonetheless, vegetation is often concentrated in them as they represent distinct ‘sinks’ for moisture. In the following, a summary is given of the key vegetation characteristics according to elevational range or ecological zone. Some aspects are also touched upon up in Chap. 6.

5.2.3.1 Main Hajar Mountain Range

5.2.3.1.1 *Submontane zone (0–) 50–500 (−600) m*

The submontane zone of the widespread harzburgite slopes and other rock types (i.e. up to about 500 m) is characterized primarily by *Acacia tortilis* and *Euphorbia larica*. This general assemblage was referred to more specifically (in phytogeographical terms) as the ‘Pseudogaillonio hymenostephanae-Euphorbietum laricae’ by Deil and Müller-Hohenstein (1996). The stands appear to correspond with the *Euphorbia larica-Gaillonia aucheri* association described in brief from southern Iran by Zohary (1973), especially as *Gaillonia* (= *Plocama) aucheri* is a regular and conspicuous associate in the Hajar Mountains (Fig. 5.15).

Fig. 5.15 Lower mountain slope in the Hatta Mountain Conservation Area (Dubai emirate) with *Euphorbia larica*, *Leucas inflata*, *Gaillonia aucheri* and *Pulicaria glutinosa*. Photo credit: Gary Brown

5.2.3.1.2 *Medium-elevation montane zone (400–) 500–1000 (−1300) m*

***Caralluma arabica-Euphorbia larica* slopes**

On the harzburgite slopes above ca. (400–) 500 m and up to about 1000 m (−1300 m), a somewhat different community type becomes more prevalent. *Euphorbia larica* is often the physiognomically dominant species. *Acacia tortilis* remains a conspicuous element in the vegetation cover up to about 800–900 m, but it is generally scattered. These are accompanied by a number of other species that vary somewhat according to location. The most notable include *Dodonaea viscosa*, *Ficus johannis*, *Moringa peregrina*, *Caralluma (= Desmidorchis) arabica*, *Ochradenus arabicus*, *Pulicaria edmondsonii* and *Stipagrostis hirtigluma*.

***Olea europaea* stands of Fujairah**

A small and remarkable population of *Olea europaea* occurs in a high-elevation area of gabbro south-west of Fujairah City. The fragmentary *Olea* stands were referred to as the 'Olive Highlands' in a detailed study published by Feulner (2014), and they represent an ecologically unique island of biodiversity. As such, they are of outstanding conservation concern.

5.2.3.2 Ru′us Al Jibal (Musandam)

5.2.3.2.1 *Vegetation zones*

In his detailed monograph, Feulner (2011) divided the vegetation of the Ru′us Al Jibal into three broad zones, characterized by habitat and elevation.

5.2.3.2.2 *Zone 1: Mountain wadi zone*

This zone includes wadi beds, wadi banks as well as associated gravel fans and terraces. In the Ru′us Al Jibal, this environment is common at elevations from ca. 100–600 m. At higher elevations, wadis tend to be narrower and rockier, and the distinction between wadi vegetation and slope vegetation (Zone 2) is less evident.

The characteristic trees are *Acacia tortilis*, *Ficus salicifolia* and *Ziziphus spina-christi*. Locally common small shrubs and dwarf shrubs include *Gaillonia* (= *Plocama*) *aucheri*, *Pulicaria edmondsonii* and *Ochradenus aucheri*. *Tephrosia apollinea*, a sure indicator of overgrazing, is omnipresent.

5.2.3.2.3 *Zone 2: Low and medium-elevation montane zone*

This zone encompasses all terrain at elevations from ca. (5–) 100–1100 m, other than the mountain wadi zone (Zone 1), and therefore includes slopes, cliffs, plateaux and basins, upper wadis and gullies as well as terraced fields.

The predominant species of Zone 2 are *Acacia tortilis*, *Euphorbia larica* and *Cymbopogon* spp. In some locations, extensive stands of *E. larica* are developed very close to sea-level. *Prunus arabica* (Arabian Almond) first appears and effectively replaces the morphologically similar (but ecologically distinct) *Moringa peregrina* above ca. 600 m.

5.2.3.2.4 *Zone 3: High-elevation zone*

This zone encompasses all terrain from ca. 1100 m to the summit plateaux and peaks at 1500–2000 m. In the UAE, areas above 1550 m are restricted to the broad summit region of Jebel Jais.

Any one of the following shrubs or dwarf shrubs can predominate in the typical plant assemblages of this zone, namely *Convolvulus acanthocladus*, *Artemisia sieberi, Dodonaea viscosa*, with the others and/or *Ephedra pachyclada* as associates. Collectively, these assemblages have been referred to as the ‘*Artemisia* steppe’ (Mandaville 1985), following the terminology of Zohary (1973), who found associations of the same species and/or genera to be characteristic of the plateaux of central Iran.

5.2.3.3 Foreland Ridges

The Foreland Ridges comprise a series of narrow, north-south trending, anticlinal ridges to the west of the main mountain front, such as Jebels Buhais, Faya, Hafeet and Nazwa. At the surface, latest Cretaceous and Paleogene marine carbonate sediments are exposed, and so the ridges are geologically distinct from the Hajar range proper. Jebel Hafeet (Fig. 5.16) has been the subject of a fairly detailed treatment of its natural history (Aspinall and Hellyer 2004), including its flora and vegetation (Brown and Sakkir 2004). In ecological terms, these isolated mountains represent distinctive 'inselberg' environments and are of considerable biodiversity interest. They have a similar vegetation structure to the main Hajar Mountains, but support a number of distinctive plant species, including, amongst many others, *Acridocarpus orientalis* (unique from a UAE perspective, but more common further to the east in Oman), *Anvillea garcinii*, *Koelpinia linearis*, *Nannorrhops ritchieana* (all Jebel Hafeet), *Dipcadi biflorum* and *Heliotropium* (= *Euploca*) *rariflorum* (Jebel Hafeet, Jebel Nazwa). The rocky slopes of some of these ridges appear to represent distinct refuges for several formerly more widespread species, where they can be locally common, including *Lasiurus scindicus*, *Rhanterium epapposum* and *Rhynchosia schimperi* (Fig. 5.17).

Fig. 5.16 Wadi Tarabat with Jebel Hafeet in the background (right). Most of the vegetation in the mountains and their associated gravel plains is found in wadis and shallow drainage channels. The main species visible is the small tree *Acacia tortilis*. Photo credit: Gary Brown

Fig. 5.17 Rocky slope of Jebel Nazwa with *Haloxylon salicornicum*, *Rhanterium epapposum* and *Rhynchosia schimperi*. Photo credit: Gary Brown

5.2.4 Freshwater Habitats

Natural freshwater habitats are generally rare in the UAE, being largely confined to the mountains where there are small numbers of permanent pools and springs as well as a larger number of temporary ones, connected by ephemeral streams (see Chap. 6).

Characteristic species of the moist to wet wadis include the rush *Juncus socotranus*, *Nerium oleander* (Oleander) and the tall perennial grass *Saccharum griffithii* (Fig. 5.18). In localized springs and seepages, the only native orchid species in the UAE can sometimes be found, namely *Epipactis veratrifolia*. This is often accompanied by the fern *Adiantum capillus-veneris* and occasionally the rare annual *Centaurium pulchellum*.

A number of artificial aquatic habitats have been created over the years, such as Al Wathba near Abu Dhabi, the lakes in Al Marmoum Desert Conservation Reserve (Dubai) and Lake Zakher (Al Ain). *Phragmites australis* (Common Reed) forms dense stands around some of these lakes whereas in some mountain reservoirs (e.g. at Hatta), the morphologically similar *Arundo donax* predominates.

Fig. 5.18 Wadi with temporary water flow and pools in Ras Al Khaimah. Two characteristic species, *Nerium oleander* and *Saccharum griffithii*, predominate here. Photo credit: Gary Brown

5.2.5 Oases, Intensive Agricultural Farms and Plantations

Freshwater oases occur throughout various parts of the country. The plains on either side of the Hajar Mountains support a relatively large number of oases, as do several desert locations in Abu Dhabi emirate. The most famous and largest desert oasis is found in the Liwa Crescent. With a ready supply of subterranean water, the Liwa supports a long chain of many individual oases that extend over a distance of more than 100 km.

Many species found in such environments are introduced annuals, often pantropical weeds, that do not become invasive. Other species are recruited from the local flora that can take advantage of the abundant resources and are not sensitive to occasional disturbance. Typical plant species of such agricultural areas include *Anagallis arvensis*, *Bacopa monnieri*, *Capsella bursa-pastoris*, *Cardaria draba* (local in the east), *Chenopodium murale*, *Eruca sativa*, *Euphorbia peplus*, *Phyla nodiflora*, *Sisymbrium erysimoides*, *S. irio* and *Sporobolus spicatus*.

Farms have sprung up in desert areas where there is a sufficient water supply, and fields of *Chloris gayana* (Rhode's grass) are dotted around the country. These tend to be poorer in species than the traditional date palm groves.

Over the past few decades, numerous forestry plantations have been created in various parts of Abu Dhabi emirate. Some of the trees used to establish the plantations are native species, but others such as *Conocarpus* sp., are not. Huge

amounts of irrigation water are needed to sustain the trees, which can lead to soil salinisation. In some parts of the region, the plantations have been abandoned.

5.2.6 *Urban Environments*

Urban areas have expanded massively in recent years. This means that large areas of what was until recently fairly intact, albeit overgrazed desert have been lost to development. For instance, it was only 20 years ago that the site where the Burj Khalifa now stands (in urban Dubai) was open desert with scattered populations of *Prosopis cineraria* on low, near-coastal sand sheets. As a consequence of this urban development, there has been a marked shift in the flora. A number of different plant species have been able to exploit these new habitats, which include, parks, lawns and gardens. Some of these plant species are indigenous to the UAE and are able to tolerate well-irrigated, anthropogenic habitats. Such species include the perennial grasses *Aeluropus lagopoides* and *Sporobolus spicatus*. Others species have been unintentionally introduced from various parts of the world, for example *Coronopus didymus*, *Fimbristylis* sp., *Poa annua* and *Sonchus oleraceus*. The status of some species, for instance *Cressa cretica* (typically found in garden beds and some plantations), is unclear as in the case of *Cressa*, it is known from saline habitats in adjacent countries where it is locally common. It may also occur naturally in the UAE in such situations. The orchid *Zeuxine strateumatica*, reported by Aspinall (2006), is a good example of a species that suddenly appeared in the country, in this case in a newly-laid golf course in Al Ain. In the context of urban ecology and biophilia as well as from a scientific perspective, urban habitats represent a treasure trove for studying such unintentionally introduced species and how they come to terms with their specific environmental conditions. To date, this aspect has hardly been explored.

Open spaces in urban settings that have not been built upon sometimes support typical desert species. For instance, in a minute patch of land near the Sheikh Zayed Road in Dubai just a few square metres in size, the dwarf shrub *Indigofera intricata* and *Coelachyrum piercii* were found growing in abundance, and *Heliotropium kotschyi* can be found in various locations growing on ‘wasteland’ in Dubai (Fig. 5.19).

5.3 Threats to the Flora and Vegetation of the UAE

The main issues affecting the flora and vegetation of the UAE are largely the same as in other arid parts of the world. They were recently highlighted by Brown et al. (2016) in the State of the Environment report prepared for the Executive Council in Dubai. A major challenge in desert areas remains overgrazing, even in some protected areas, which leads to a massive reduction of vegetative cover or substantial

Fig. 5.19 Urban 'wasteland' can constitute an interesting refuge for biodiversity, both flora and fauna: here with *Calotropis procera* (an indicator of disturbance), *Heliotropium kotschyi* and *Zygophyllum qatarense* near the Sheikh Zayed road in Dubai. Photo credit: Gary Brown

shifts in dominant plant species, including a severe decline of most palatable species (Fig. 5.20). This also results in the impoverishment of the fauna. Apart from numerous scientific publications from the country (e.g. Böer 1999; Aspinall 2001; Brown et al. 2006; Gallacher and Hill 2006, 2007; Gallacher 2007; Tourenq and Launay 2007; Brown 2008; El-Keblawy et al. 2009; Alzahlawi et al. 2019), overgrazing is also highlighted as a major contributory factor to land degradation and desertification in the UAE's federal *State of the Environment Report* (MOEW 2015). The term 'desertification' is somewhat controversial, but is used in accordance with Dregne (1986), referring particularly to a reduction in plant productivity, a decline in species diversity and the loss of soil resources (see Fig. 5.24 below). Desertification was a topic that was 'en-vogue' several decades ago, but the seriousness of this menace is beginning to be recognised again in recent years.

Native or subnative species that expand rapidly in response to ecosystem degradation are termed 'expansive' species or 'increasers' ('subnative' refers to species native to adjacent areas or ecosystems). In more extreme cases, they are highly detrimental to ecosystem functioning. The shrub *Calotropis procera* (Sodom's Apple), which is particularly common in parts of the north-east of the country, is a good example of an expansive plant species that has had a major transforming role to the detriment of biodiversity in desert settings in the UAE. In the mountains and adjacent plains, common expansive species are the woody-based perennial herb *Tephrosia apollinea and* the toxic dwarf shrub *Rhazya stricta*. Most species of

Fig. 5.20 Heavily overgrazed *Prosopis cineraria* area. Some of the trees have been severely lopped to provide forage for domestic livestock. The stumps in the ground layer are dead remnants of *Haloxylon salicornicum*, which were not able to tolerate the massive grazing pressure. Note the virtual absence of a ground layer, despite the favourable spring when the image was taken. Photo credit: Gary Brown

Fagonia where they occur in large amounts can be regarded as indicators of overgrazing and ecosystem degradation.

Heavily-stunted individuals of *Lycium shawii*, a shrub that is browsed by camels, are a common sight in north-eastern parts of the country where the species naturally occurs. Other effects of massive land degradation will only become more obvious in future decades. For instance, it appears that all of the *Acacia* woodland of the alluvial plains is now extremely degraded (Fig. 5.21), and recruitment of young trees is severely impeded in most locations. If there are no trees to replace the older ones, which will eventually die off, the woodland will disappear completely in the medium term. This process has already been described in detail for parts of the Arabian Peninsula by Chaudhary (2010).

Relatively few desert annuals appear able to withstand heavy grazing pressures, but some of the more obvious examples include, in the north-east at least, *Malva parviflora* and *Emex spinosa*.

Construction activities are underway in many locations nowadays, but it is the coastal habitats that have suffered most massively from development to date. This is particularly the case along the entire coastline east of Abu Dhabi island. There has also been substantial development on the Indian Ocean coast over the past two decades. Indirectly, other issues have led to the demise of coastal areas. For example, it is often the case that coastal vegetation in the region is equated solely to

Fig. 5.21 Highly degraded *Acacia tortilis* parkland. The demise of this vegetation type typically proceeds slowly and easily goes unnoticed due to the relative longevity of the trees. It is a typical example of the shifting baseline syndrome. Photo credit: Gary Brown

mangroves. In fact mangroves account for only a very small percentage of the total coastal vegetation, meaning that other vegetation types are largely or completely ignored. Such narrow perspectives coupled with the focus on specific vegetation types deemed worthy of protection have severe conservation repercussions, as has happened to the 'coastal white sand vegetation' (see above).

In the mountains, two factors are having a particularly negative effect on the flora and vegetation, namely quarrying and road-building (see Chap. 6). Both leave large scars on the landscape, often visible from considerable distances, that will persist for decades at least, and the latter is opening up areas to the wider public, initiating a chain of events that ultimately leads to the simplification of the vegetation.

Habitat fragmentation is an issue that not only affects the fauna, but also the flora. The increasing degradation and fragmentation of habitats with intact and species-rich vegetation, which often remain as islands in an otherwise degraded landscape, could be expected to have implications for gene flow mediated through pollination processes. This would be especially the case for rare species that remain in island-like remnants, potentially leading to genetic erosion including inbreeding depression (Aguilar et al. 2019). This topic has not been addressed so far in the UAE or the wider region.

Off-road driving is a major issue that causes soil compaction and the direct destruction of vegetation, as well as disturbance to the fauna (Brown and Schoknecht 2001).

It is unclear to what extent groundwater abstraction has had an impact on the vegetation. Deil and Müller-Hohenstein (1996) suspected that the dramatic lowering of the groundwater table may have seriously affected formerly dense *Prosopis cineraria* woodlands in parts of the desert.

The invasion of ecosystems by non-native species is a global phenomenon, which can have major ecological and economic consequences. The impact of such introduced species can be very serious if so-called 'transformers' are involved, species with the potential to alter entire ecosystems (Richardson et al. 2000). A distinction can be made between these invasive alien species and expansive native or subnative species, but the overall effects on the ecosystem can be equally devastating.

At present, the UAE has been affected by relatively few invasive alien plant species, likely as a result of the extreme local climate relative to natal sites of many introduced species. The most serious is undoubtedly *Prosopis juliflora* (mesquite), which has wreaked havoc in other parts of mainland Arabia. In the UAE, it has its stronghold in some near-coastal areas of the Northern Emirates (Fig. 5.22), where it forms open woodlands and outcompetes the native *Prosopis cineraria* (ghaf), but scattered trees occur in many areas elsewhere.

Climate change is an issue that requires special attention. It is clear that the global climate is undergoing rapid changes, without doubt driven primarily by human activities (see Chap. 3). At present, it is very difficult to assess how the climate is changing in particular regions—partly because of the inherent problems of differentiating between short-term fluctuations of weather patterns over several years and

Fig. 5.22 *Prosopis juliflora* invading a stand of *Prosopis cineraria* (ghaf) in a near-coastal area of the Northern Emirates. The ground layer consists to a large extent of the annuals *Emex spinosa* and *Malva parviflora*, both tolerant of heavy grazing. Photo credit: Gary Brown

actual long-term changes. Although it is generally accepted that the climate is currently warming at an unprecedented rate, the outcomes may not be as expected over the longer term. From a biodiversity perspective, the responses to climate change are extremely complex due to the myriad of factors and interdependencies that affect the ecological performance of individual species under specific climatic conditions. It is also important to realise that rapid shifts in climatic conditions will produce clear 'winners' apart from 'losers'. Although it is perhaps reasonably straightforward to monitor, for example, how the ranges of certain species may be changing in response to changes in climate, overall ecosystem responses are far from clear. Whereas fauna and flora have had to come to terms with changes in the climate in the past, the current situation is far more worrying because of the speed of apparent changes that allows organisms no time (in evolutionary terms) to adapt.

However, it is important to emphasise that although climate change is a key issue, some of the others listed above are, currently at least, much more threatening from a biodiversity perspective in terrestrial ecosystems, but they have not received the same degree of general attention. This applies in particular to the massive overgrazing issue, as was clearly underlined by Le Houérou (1996) and Brown and Mies (2012) for Socotra. In fact in a very recent study, Caro et al. (2022) confirm this view and conclude that although climate change is highly relevant issue, it detracts focus and effort from the primary threats to biodiversity, namely habitat destruction and overexploitation. This is apparent throughout the Arabian Peninsula when comparing areas that have long been protected from overgrazing from those that have not (e.g. Brown 2001; Brown and Al-Mazrooei 2003; Al-Rowaily et al. 2015), including for the UAE (Figs. 5.23 and 5.24).

Finally, a major problem exists in that many people in the region are unaware of what desert ecosystems previously looked like, even in the not too distant past. This is in part due to the lack of reliable records from the region. In this context, and due to the widespread nature of this problem, the 'shifting baseline syndrome' should be mentioned, which has received much attention globally. The concept was first described by Pauly (1995), examining the problems of massively depleted and declining fish stocks. He pointed out that fisheries scientists at the beginning of their careers perceive then current stock sizes and species composition as the norm (baseline) against which subsequent changes are assessed. With generally declining stock sizes, the following generation has a lower perception as to what constitutes the norm. In more general terms therefore, the shifting baseline syndrome (SBS) describes the incremental lowering of standards that results in each new generation lacking knowledge and experience of the historical, and presumably more natural condition of the environment. The shifting baseline syndrome can be applied unreservedly to the situation of the terrestrial ecosystems of the UAE. The strong implication of SBS is that with the continuing deterioration of the natural environment, baseline standards for environmental health will continue to decline, which represents an enormous challenge for the conservation, restoration and management of terrestrial ecosystems in the country. The gradual demise of the *Acacia tortilis* parkland throughout much of its occurrence in the Arabian Peninsula is a typical example of SBS, as indicated above.

Fig. 5.23 Undulating sand sheets with the dwarf shrub *Haloxylon salicornicum* were once widespread in the north-west of the UAE, but are now restricted to areas that are protected from grazing such as here in the Yaw Al Debsa Protected Area (Abu Dhabi emirate). The *Haloxylon* dwarf shrubs play a key role in stabilising the sand sheets and protecting them from wind erosion. Photo credit: Gary Brown

Fig. 5.24 Seriously degraded landscape immediately outside of the Yaw Al Debsa Protected Area where overgrazing and other detrimental activities such as off-road driving are prevalent. Note the loss of the undulating sand sheets to reveal the underlying compact surface, which is generally less favourable for plant establishment. Photo credit: Gary Brown

With regard to how to tackle some of these key issues, Aspinall (1996) recognised many of the key biodiversity challenges facing the country and proposed a network of protected areas comprising 41 distinct sites. Although ornithological criteria played an important role in the selection of these sites, many of them were of high conservation value for other groups of organisms, too. In the meantime, the various emirates have designated a number of protected areas, some of which correspond to those suggested by Aspinall. Now, effective management plans will need to be developed and implemented to help protect their biodiversity.

Brown and Böer (2004/2005) compiled the first detailed habitat classification scheme for Abu Dhabi emirate, closely aligned with the general approach of the '*Interpretation Manual of European Union Habitats*', which provides the legislative foundation for all conservation planning in the EU, and was last updated in 2013 (European Commission DG Environment 2013). The Abu Dhabi scheme, still in use today, provides a list of 'priority habitat types', i.e. ones of major conservation concern, which remain highly relevant. In the meantime, it has been updated to cover the whole of the UAE (Brown in prep.). This means that at a fundamental level, sufficient information is available to facilitate the decision-making process for a rigorous biodiversity policy. Mapping of habitats has been conducted in some areas based primarily on a remote-sensing approach. However, as personal experience has shown throughout the Arabian Peninsula, this in itself is often not effective in discriminating and delimiting habitats and vegetation units for conservation purposes. That can only be achieved if supported by rigorous field-based studies, preferably conducted by experienced persons. Field-based studies are also the only meaningful way to collect exhaustive 'raw' biodiversity data.

On a welcome note, Abu Dhabi emirate has recently introduced a grazing law (Abu Dhabi Law No. 11, 2020), which, once fully implemented by the Environment Agency—Abu Dhabi (EAD), should help alleviate the substantial pressure on the rangelands that has led to the denudation or simplification of the vegetation cover over substantial tracts of the desert. To improve ecosystem functioning, however, wide-ranging restoration measures are required given the extent of degradation.

5.4 Recommended Readings

For a general overview of terrestrial habitats of the UAE, see Brown and Böer (2005). For details on the coastal vegetation of the western and southern Gulf, see Brown et al. (2008) and for the Arabian region as a whole see Ghazanfar and Fisher (1998).

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