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Characterisation of the Wadi Wurayah Catchment Basin, the First Mountain Protected Area in the United Arab Emirates

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ABSTRACT

Wadi Wurayah, in the Emirate of Fujairah, United Arab Emirates, lies within a priority WWF Global 200 Ecoregion (Ecoregion 127, Arabian Highlands and Shrublands), sheltering a rich diversity of rare and endangered mountainous and freshwater habitats and species, and providing opportunities for the sustenance and revival of local livelihoods. Emirates Wildlife Society-World Wide Fund for Nature in collaboration with the Fujairah Municipality initiated a project to declare the whole catchment basin as officially protected with the aims to help establish a sustainable protected area integrating local tradition and lifestyle with the conservation of inimitable biodiversity and habitat by providing a model of unique economical incentives to the region. Over 300 species of plants grow in the area,

including the country's unique orchid, *Epipactis veratrifolia*, as well as wetland species. Twelve species of mammals were observed, including the Arabian Tahr, Mountain Gazelle, Blanford's Fox and, possibly, Arabian Leopard, all considered Threatened by the International Union for Conservation of Nature (IUCN). So far, 74 species of bird (of which 25% are considered of national conservation interest) have been recorded, including the Bonelli's Eagle, Barbary Falcon, Asian Houbara Bustard and probably Hume's Tawny Owl. The wadi hosts thirteen reptile and amphibian species of which five are endemic to UAE and northern Oman mountains: Blue-tailed Lizard, Jayakar's Oman Lizard, Bar-tailed Semaphore Gecko, Banded Ground Gecko, and Oman Carpet Viper. Endemic to the Arabian Peninsula and considered endangered by IUCN, the Garra fish is found in the wadi. The collection of insect samples revealed 74 invertebrate families, including 19 arthropod species new to science. So far, 29 heritage sites have been recorded and mapped, including bedu settlements, ancient Islamic graveyards, pre-Islamic tombs, 15th to 18th centuries AD porcelain and pottery fragments and one petroglyph (rock carving) site. Social surveys of resident and non-resident local people were conduced as well showing a positive response to the creation of a protected area. Because of its unique hydrogeological system with permanent pools and streams, the Wadi Wurayah area has a strong potential in the Fujairah Emirate for (1) management and conservation of fresh water resources, (2) conservation of its unique fauna and flora, (3) conservation of its cultural heritage, (4) opportunity of local capacity building and involvement of several departments of Fujairah Municipality around the same project, (5) involving local communities in the management and (6) proposing an alternative and complementary tourism activity to the coastal development in progress in the Emirate

Key Words: United Arab Emirates, Mountain Protected Area, Biodiversity, Arabian Tahr

INTRODUCTION

The wealth brought by oil and gas revenues has resulted in drastic changes in the whole Arabian Peninsula and the United Arab Emirates (hereafter "UAE") in particular. The UAE's population has increased by 16 times in the last 30 years, with a population growth up to 6.9% (UAE Yearbook 2006). In the same period the UAE natural and social environment has undergone dramatic changes with substantial development of infrastructures (roads, housing, industries, etc.) and agriculture (farms, forest plantations) and drastic modifications of lifestyle with the end of nomadism, modernisation of hunting and modernisation of fishing (Gulf Research Center 2007).

Much of the development ignited by the economical growth initially confined to the coastline, has spread to the mountains. The UAE's first cement factory opened in the Ras al Khaimah Emirate in 1975 with an annual capacity of 550,000 tons (=Mg). The formidable coastal development initiated in Dubai during the last decade induced an increasing demand for cement as well as building material (rocks, aggregates, limestone, etc.) in the 1990s. Except for gypsum and some additives, the raw materials for cement and building material are locally available in the mountainous emirates of Sharjah, Ras al Khaimah and Fujairah. Crushing and quarry licenses dramatically increased in Ras al Khaimah and Fujairah to provide material quasi on site and not rely on overseas importation. In 2001, there were 11 cement factories with an annual capacity exceeding 8 million tons in the whole country. Given the pace of development in the country and the demand for building materials, the market for cement is expected to rise by 10 to 15 per cent annually to a total of around 23 million tonnes per annum within the next five years (Ghanem 2001, UAE Yearbook 2003, UAE Yearbook 2006).

Fujairah is the only Emirate exclusively on the East Coast and one of the most fertile of the UAE, possessing spectacular and varied scenery which encom-passes mountain, alluvial plain and coastal habitats. A unique tribal existence, based on seasonal nomadism, wild honey gathering and shaped by the harshness of the environment, has given rise to a distinct agricultural system. Although this way of life is less practised today, the emirate's mountain heritage remains immensely valuable and is seen nowhere else in the UAE.

With the saturation of the Dubai and Abu Dhabi emirates' tourism and real-estate markets, developers look at new areas in the region to develop and the pressure is increasing on the natural habitats of Fujairah. The government of Fujairah, through the Municipality, decided to start targeting terrestrial areas for protection. Being a unique ecosystem in the UAE of perennial freshwater habitats, in the form of succession of springs, pools, riffles/streams and waterfalls and hosting a rich biodiversity of fauna and flora in an area of outstanding natural beauty which is already an established popular tourist attraction, the Wadi Wurayah

catchment area was a ideal candidate for the establishment of a protected area. The Emirates Wildlife Society (hereafter "EWS") in association with the World Wide Fund for Nature (hereafter "WWF") and the Fujairah Municipality initiated a survey to evaluate the potential and the feasibility of the creation of a protected area. This paper covers presents a synopsis based on the compilation of technical findings from the survey team since 2006.

PHYSICAL CHARACTERISTICS

When not mentioned, the following information is extracted from these sources: Atkins (1993), Joudah (1994), Rizk and El Etr (1997), Murad and Krishnamurthy (2004), Brook (2006), UAE Ministry of Energy and British Geological Survey (2007a 2007b, 2007c, 2007d).

Location

The Wadi Wurayah catchment basin expands from UTM 2815831.815 (North) to 2800263.544 (North) and 420127.757 (East) to 430850.218 (East) between the towns of Kohr Fakkan (Sharjah Emirate) and Bidiyah (Fujairah Emirate) on the Oman Gulf Coastline (Figure 1). Located in the Shimayliyyah Massif, the catchment basin is flanked on its west side by the town of Masafi (Fujairah and Ras al Khaimah Emirate). It is part of the great Hajar Mountain range which parallels the East coast of the UAE, extending from the Musandam Peninsula in the North to Oman in the South. The whole catchment is about 129 km^2 in area and has a maximum elevation of 956 m.a.m.s.l. The catchment contains 371 separate streams of 301km total length and the dendritic drainage branches from six main wadis.

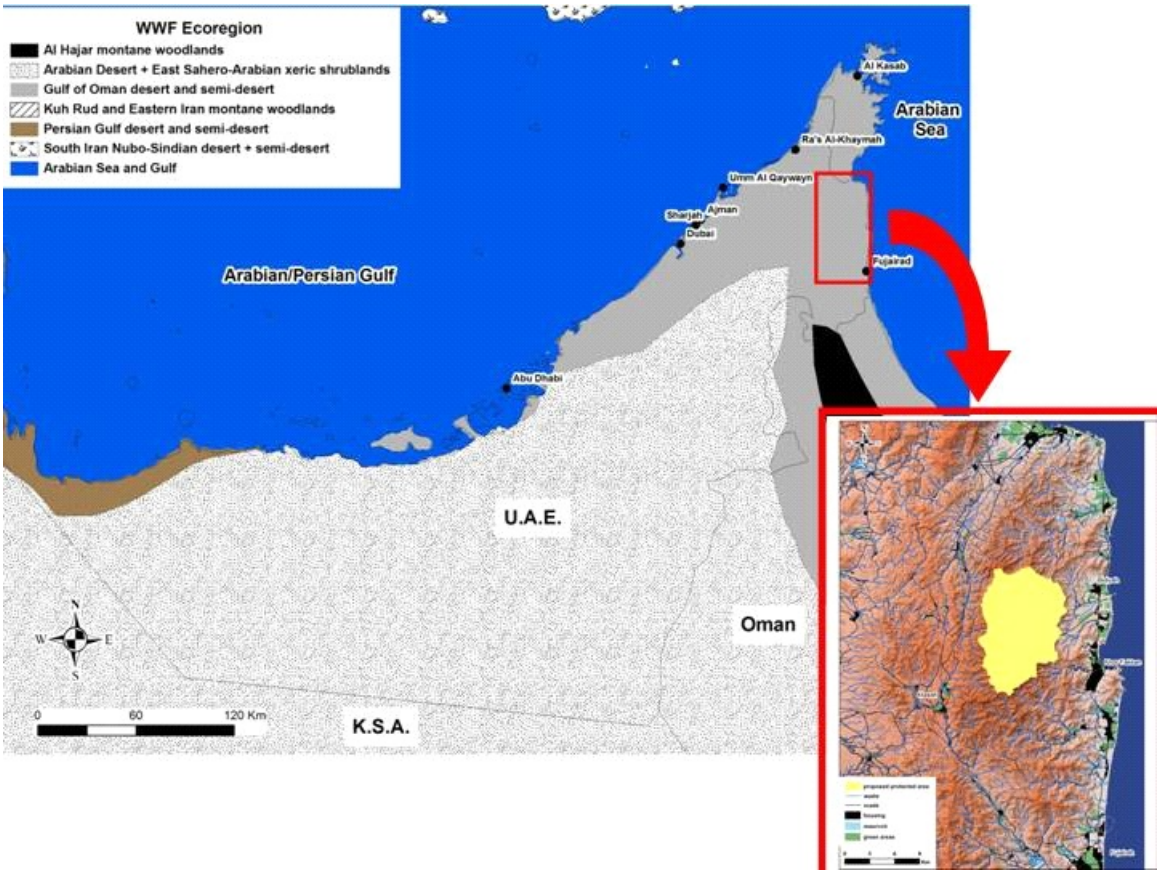

Figure 1. Location of the study area. The protected area is illustrated in the insert. The ecoregions are characterised according to WWF (Olson and Dinerstein 1998).

Five ecoregions on the 1,507 identified in the world by the WWF (*http://www.worldwildlife.org/wildworld*; Olson and Dinerstein 1998) are present in the UAE: Al Hajar mountane woodlands, Arabian Desert and East-Saharo-Arabian desert and xeric shrublands, Gulf of Oman desert and semi-desert, Persian Gulf desert and semi-desert, and Arabian Sea (Figure 1). The UAE contains also two of the "Global 200"– the most biologically distinct terrestrial, fresh-water and marine ecoregions of the planet: the "Arabian Highlands and Shrublands" and the "Arabian Gulf and Sea". The Global 200 were selected for their species richness, endemism, higher taxonomic unique-ness, unique ecological or evolutionary phenomena, global rarity of habitats, intactness and representation. Their conservation status of ecoregions was assessed in the tradition of IUCN Red Data Book categories for threatened and endangered species. Wadi Wurayah lays itself within the priority WWF Global 200 Ecoregion (Ecoregion 127, Arabian Highlands and Shrublands), sheltering a rich diversity of rare and endangered mountainous and freshwater habitats and species, and providing opportunities for the sustenance and revival of local livelihoods (*http://www.worldwildlife.org/wildworld*; Olson and Dinerstein 1998).

Climate

The climate of the catchment can be described from the nearest comprehensive rain stations at Masafi (9 km south west from Wurayah catchment centre) and a summary is provided in Table 1. The climate of Wadi Wurayah is characteristic of a hot, hyper-arid mountain desert environment. Temperatures are highest during the period of April to October, and are coolest from November to March. In summer, typical daytime temperatures can reach almost 50ºC. The atmospheric relative humidity (RH) varies between less than 1% and 100%. Minimum RH values (<10%) are recorded mainly during the summer between April and August. Maximum RH values (>90%) are observed during autumn-winter (September-January) and correspond to night dew formation. According to Boer (1997) the catchment lies in a sub-humid bio-climatic zone and in an area which is the wettest in the UAWE. It is not surprising therefore that the perennial waterfalls are unique to Wadi Wurayah. Annual precipitation is however highly variable, as with the rest of the UAE. The majority of rainfall events occur during winter months (October-April) from cloud bands that migrate from the eastern coast of Africa, or from the frontal systems that originate in the Mediterranean when the Siberian high pressure shrinks north-eastwards by late winter, or may be due to the southward advance of active westerly troughs over the south western part of the Arabian Peninsula. Rainfall can occur during summer months with clouds drifting from the Indian monsoon over the Arabian Sea, afternoon convective clouds due to orographic effects, rare cases of the Inter Tropical Convergence Zone shifting northward over UAE and causing overcast weather and thunderstorm activity or the temperature contrast between land and sea (at the hottest time of the year) which may be large enough to produce what's known as a sea breeze front that may give traces of rainfall along the coast (Figure 2a). Interestingly, the data for the four closest weather stations surrounding the catchment shows that the rainfall in Wadi Wurayah might be closely linked with the Pacific Decadal Oscillation, or ENSO El Nino and La Nina events. For all El Nino years, the annual rainfall is above average for that year including 1995, the strongest recorded El Nino year, where maxima are reached in Khor Fakkan (Figure 2b).

Table 1. Climate data from Masafi Weather Station, Fujairah, UAE.

Parameter	Mean	Maximum	Minimum
Rainfall (mm annual)	179	443.8 (1976)	27.6
Air Temperature (ºC)	26.8	43.0 (June)	11.4 (January)
Relative Humidity (%)	49.0	95.0 (February)	10.0 (May)
Pan Evaporation (mm/d)	10.7	21.2 (June)	3.1 (January)
Surface wind speed (km/d)	181	698	11.0
Sunshine (hours)	9.5	11.0	-

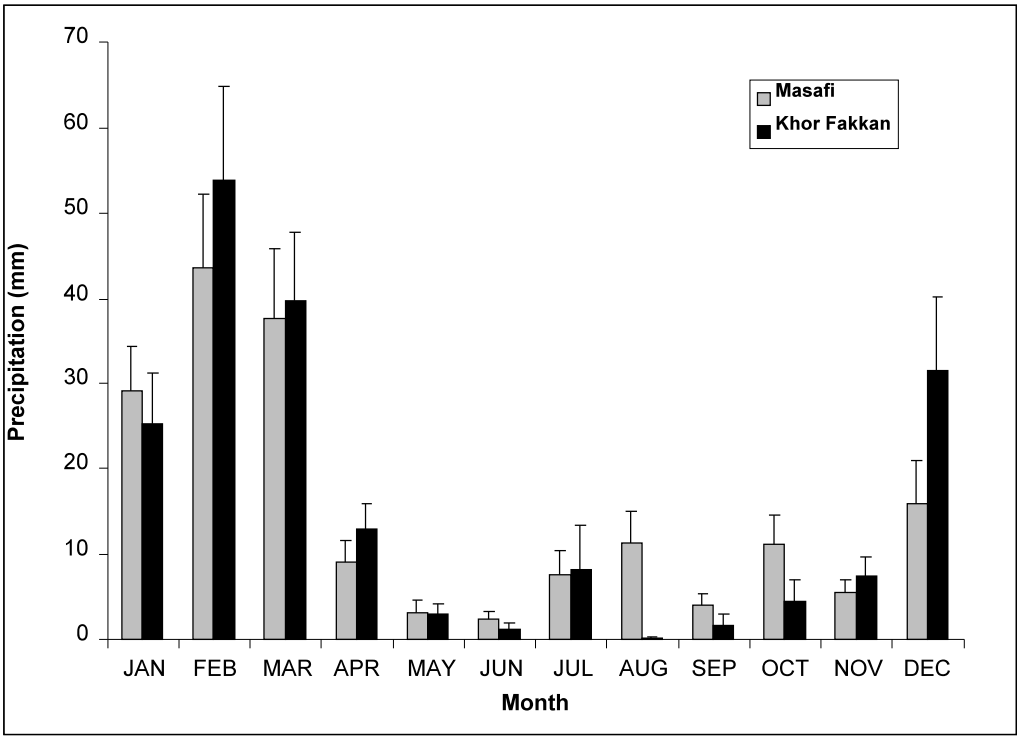

Figure 2a. Average (±SE) monthly rainfall in Wadi Wurayah area (Masafi and Khor Fakkan) for the period 1968 to 2004.

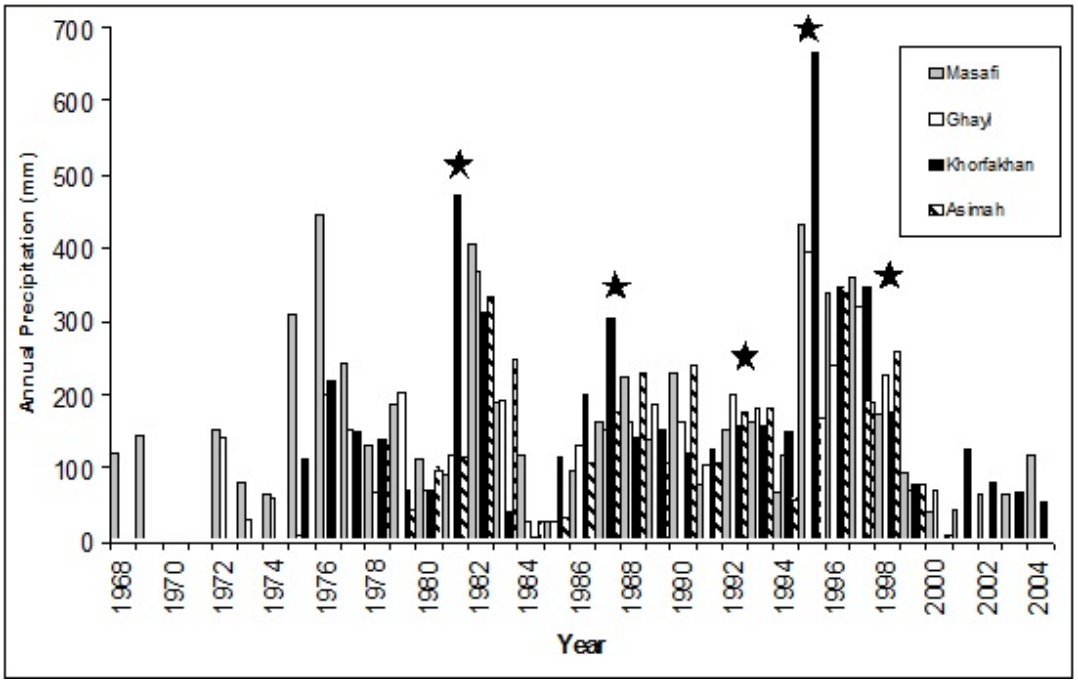

Figure 2b. Annual rainfall at four stations surrounding Wadi Wurayah, Fujairah, UAE for the period 1968-2004. Stars indicate strong El Nino years. Note: data from 2000 to 2004 shown only for Khor Fakkan and Masafi.

Geology

The geology includes basic and ultra – basic igneous rocks as bedrock, including the world famous Semail Ophiolite suite. Lying on top of bedrock, are relatively thick deposits of old and recent alluvium, comprising boulders, cobbles, gravels and sands, laid down in a high energy fluvial environment. Whilst the former does contain some groundwater in fractures and cavities, it is the latter, quaternary gravels which are the primary aquifer in the catchment, having an average permeability of about 5 m/d and a porosity of 10-15 %. The Ophiolite complex (bedrock) is cut by deeply incised wadis which have subsequently been unfilled with fluviatile deposits. The Upper Cretaceous to Pre-Permian Semail Ophiolite suite comprises mostly gabbros, ultra-basics and fine to coarse grained granite and granodiorite as minor intrusions. The Upper parts of the catchment are mostly ultra basics, comprising peridotite, serpentinized peridotite and serpentinite, with locally banded Magnesite. Thin chrysotile and calcite veins are common. Under extreme temperature, the calcite has transformed to marble. The serpentinite is generally highly fractured and rock falls and minor avalanches are seen along contact planes. The lower part of the catchment contains complex zones of gabbro with intermixed ultrabasic rocks. The upper catchment wadis and lower wadi plains comprise wadi gravel deposits. These deposits comprise rounded gravel, cobbles and boulders, usually within a poorly sorted sand/silt matrix. In the vicinity of active wadis, the gravel becomes increasingly compact with depth. Thick gravel terraces are seen 2-3 km upstream of the Khor Fakkan – Masafi road and continue for a distance of 9-10 km into the catchment. These terraces are very compact and cemented with a shallow cover of loose boulders, cobbles, gravel and sand. The fluviatile deposits are boulders, gravel, sand and silt and occur within the active wadis and in old undifferentiated terrace deposits and cemented wadi walls. The sediments spread out into an outwash fan downstream of the recharge dam. Structurally, the Shimayliyyah Mountains are part of a complex anticline system which has been subject to thrusting and overfolding during emplacement of basic igneous crustal rocks. The catchment contains numerous structural lineaments trending mostly NNE-SSW and NW-SW and these structures control wadi directions in the upper catchment. There are three major sets of faults in the region: NW-SE, NE-SW and N-S.

Hydrology

Rainfall provides low salinity and low temperature run off water which infiltrates the fractured ophiolite and the recent and older wadi gravel and gravel terraces in the upper parts of the catchment. Run-off quickly finds its way downstream in flash floods which also provide significant recharge to the alluvial aquifer in the mid part of the catchment, ultimately culminating in storage for the Al Wurayah recharge dam. Undulations within the impermeable igneous bedrock are filled with shallow alluvium. Upstream of the contact spring waterfall, springs bring water to surface both at the contact between bedrock and alluvium and also at the contact between cemented and uncemented gravels, the former acting as impermeable barriers forcing water into the wadi channels. Fractures within the cemented gravels also produce springs. Combined flows from contact springs near the contact spring waterfall were approximately 2-3 L s^{-1} at time of visit (January 2006). The area receives an average annual rainfall that provides a total of 18.7 Mm^3 yr^{-1} available water with an average of 2.24 Mm^3 yr^{-1} occurring as run-off; due to the particular geology of the area, this creates a unique hydrogeological system in the United Arab Emirates of perennial streams, falls and pools. The quality of water is exceptionally good and the hydro-chemical analyses indicate that the spring waters meet, from a chemical point of view, all World Health Organization standards for drinking water and also standards for bottled water. Wurayah waters can be classified as Magnesium Bicarbonate, a type which is indicative of a recently recharged and active water resources regime, slightly alkaline with a mean pH value of 8.3 (range 8.1-9.1). Average laboratory Total Dissolved Solids are 310 mg L^{-1} (range: 257-403). Average Dissolved Oxygen varies between 5.2 and 11.22 mg L^{-1}. The nitrites average concentration values in Wurayah surface waters of freshwater habitats did not exceed 0.02 mg L^{-1}, the nitrates average concentration value being 5.76 mg L^{-1}. Mean temperatures in pool habitats ranged from 22 to 28ºC owing to their diverse physical nature and location.

WILDLIFE

When not mentioned, the following information is extracted from the following sources: EWS-WWF (2006), Sawaf (2006a), Sawaf (2006b), Smart (2006), Selwan (2006).

Flora

Wadi Wurayah hosts about 300 plant species (Al Hamoodi, under press). There were no aquatic macrophytes recorded throughout the entire survey, the only aquatic vegetation present was algae ranging from thin films of epilithic algae growing on rocks and gravel to fine filamentous, green algal species in the riffles and floating mats of brown algae in the static pool environments. Table 2 lists the major plants found in the area along with their characteristics and traditional uses to highlight the importance of their preservation. The most prevalent plants species in Wadi Wurayah were the woody perennial, namely *Convolvulus virgatus*, *Lycium shawii, Boerharvia elegans* and *Heliotropium spp*. Major trees identified were *Acacia tortilis*, *Moringa peregrina*, *Ficus cordata* and *Ziziphus spina-christi.* The characteristic flora of higher elevation plateaus and slopes are *Acacia tortillis*, *Lycium shawii*, in combination with several woody perennials such as *Euphorbia larica* and *Tephrosia appolinea*, this constitutes a common plant association. Wadi Wurayah is characteristic for its vegetation associated with the presence of temporary and/or permanent fresh water sources (*Arundo donax, Nerium oleander, Saccharum ravennae)*. The orchid *Epipactis veratrifolia*, which usually lives in association with the fern *Onychium divaricatum* is of particular interest, being the unique Orchidaceae found in the UAE. It is worthy to mention that *Tamarix aphylla, Moringa peregrina, Typha domingensis* were also recorded and are considered uncommon/rare in UAE (Western 1989, Jongbloed 2003). Abandoned date palms (*Phoenix dactilifera*) were located in the lowest wadi elevations, as signs of old nearby settlements. Finally, an established oasis down stream of the Wadi Wurayah catchment area constitutes areas of intensive cultivation of economically important crops: dates, mangoes, guavas, citrus, bananas, vegetables and a number of forage crops.

Fauna

As well as the presence of permanent water pools, the most important feature of the Protected Area is its particular mammalian fauna. A total of 12 species of wild mammals on the total of 20 observed or suspected in the region, were recorded during the survey within the Wadi Wurayah Protected Area (Table 3). At an international level, species like the Arabian Tahr (*Hemitragus jayakari*) and, the Arabian Leopard (*Panthera pardus nimr*), are considered "Critically Endangered" according to the IUCN Red List of Threatened Species (IUCN 2006). The Mountain Gazelle (*Gazella gazella cora*), and the Blanford's Fox (*Vulpes cana*) present in Wadi Wurayah are classified as "*Vulnerable*", according to the IUCN Red List, the Caracal Lynx (*Caracal caracal schmitzi*) and Gordon's Wildcat (*Felis silvestris gordoni*) being considered as locally endangered. The Arabian Tahr is endemic to UAE and Oman arid highlands (Munton, 1986). Nowadays, with Jebel Hafeet (Al Ain; Hellyer and Aspinall 2005), Wadi Wurayah is one of only two places in the UAE where a small population of Arabian Tahr still survives. Its survival is closely linked with the presence of permanent water holes where it can drink regularly during the hot season. Results of a survey of 150 local residents show that the Red Fox (*Vulpes vulpes arabica*) is the species most commonly seen in the area, but also a general decline of 72% in sightings of five mammal species: Red fox, Arabian leopard, Caracal Lynx, Mountain Gazelle and Arabian Tahr in Wadi Wurayah during the last 15 years (EWS 2006). Such decline may be due to several factors like: overgrazing, habitat fragmentation and urbanisation, wildlife poaching and persecution, habitat degradation (EWS 2006). Feral domestic Goats (*Capra aegagrus hircus*) and Feral Donkeys (*Equus africanus*) escaped or released in the wild after the introduction of motorised vehicles in the UAE in the 1990s were observed as well.

Seventy-three species of birds in total have been recorded within the Wadi Wurayah region so far. Of these 73 species, 5% are considered endangered worldwide by the IUCN and 25 % are of conservation concern for the UAE. The four species of international conservation concern are: Egyptian Vulture (*Neophron percnopterus*), Lappet faced Vulture (*Torgos tracheliotos*), Lesser Kestrel (*Falco naumanni*) and Houbara Bustard (*Chlamydotis macqueeni*) (Table 4). The bird species include the typical mountain resident birds; for example Hume's Wheatear (*Oenanthe alboniger*), Sand partridge (*Ammoperdix heyi*), Desert Lark (*Ammomanes deserti*), and Northern Palaearctic migrant species such as Sparrowhawk (*Accipiter nisus*), Blue Rock Thrush (*Monticola solitarius*), Kingfisher (*Alcedo atthis*), Grey Wagtail (*Motacilla cinerea*), and Red-tailed Wheatear (*Oenanthe xanthoprymna*) to name a few (Aspinall 1996, Richardson 1997, 2003). These are attracted by permanent water holes and their luxurious vegetation. Fifty-nine percent of the species (37) recorded in Wadi Wurayah region are known or are thought to be present during the breeding season in the area, including species of national conservation interest such as

Table 2. Common plant species identified in Wadi Wurayah. A.N: Arabic Name, E.N: English Name

Scientific Name	Arabic Name * Common English Name	Status	Traditional uses
Onychium divaricatum			
Adiantum capillus-veneris	sabaha, sha'ar el ard * maidenhair fern	Common	Infusion for chest diseases as an expectorant.
Nerium oleander = *Nerium mascatense*	deflah, haban * oleander		Fairly common All parts poisonous, not grazed. Steam from boiled leaves inhaled to relieve sinusitis. Leaves used as insecticide. Pounded leaves applied to skin for itch, ulcers and tumors.
Calotropis procera	'ushar, shakjr, 'asur, ashkar * Sodom's apple	Locally common	Milky sap is poisonous. Latex used to treat all kinds of skin ailments, toothache. Powdered dried leaves in small amounts to treat worm infestations. Dried leaves smoked for asthma. Underbark for repairing and decorating household items. Hairs attached to seeds used to stuff pillows.
Heliotropium calcareum	khashfah	Common	
Convolvulus virgatus	Rub al-risha, adlam	Common	
Cyperus conglomeratus	thenda, ayzm, chadrum, qassis, rasha * cyperus	Ubiquitous	Sedges once used to make ropes, baskets and mats. Also used as fuel. Rhizomes sometimes used as food.
Euphorbia larica	isbaq, ibriq	Very common	Dried branches used for thatching of roofs. Latex used as glue to catch birds.
Saccharum ravennae		Locally common	Often found grazed to the ground.
Arundo donax	ghaab, qalam * giant reed	Common	Stems traditionally used for fencing, for making musical instruments and tools.
Cymbopogon commuttum	alklathgar, sakhbar, hamra', idhkhir, khazzab * incense grass	Common	In India and Pakistan, *Cymbopogon spp*. cultivated for extraction of aromatic oil citronella (perfume, insect repellant)
Lavandula subnuda	haraq, sawmar	Common	Crushed leaves are insect repellant.
Tephrosia apollinea	Dhafra, omayye, nafal	Very common	Leaves boiled with water used as eardrops for earache. Powdered bark with water pout into camel's ears to remove ticks. Powdered leaves applied as a paste to relieve wounds.
Acacia tortilis	samr, salam	Very common	Extensively browsed by camels and goats.
Ficus cordata *Subsp. salicifolia*	teen al barri, jarf, lithab * wadi fig	Locally common	Sap of new leaves used to treat bruises and scorpion stings. Milky juice from stem used to remove warts. Also applied on skin inflammations. Underbark used in tanning of leather to give it a dark red colour.
Moringa peregrina	shu', yasar, baan, 'aweyr, bayreh, terfaal, yayn * wild drumstick tree	Uncommon	Oil extracted from seeds used to treat headaches, fever, muscle pain and burns. Mixed with cloves and cardamom oil used during labour as a drink. Extract of leaves rubbed on skin to treat skin rash.
Boerharvia elegans	hadimdam, hamra, shuayrqah, alshams, sulaykait mal jebel		Common
Epipactis veratrifolia	* helleborine orchid	Fairly common (becoming rare)	Typically grows in association with the fern (*Adiantum capillus-veneris*)
Pteropyrum scoparium	sidaf	Common	Leaves are eaten to treat dyspepsia and as a blood purifying tonic.
Rumex vesicarius	hummad * sorrel, bladderdock	Common	Leaves have a citrus taste and are eaten as salad green or cooked with meet. Eaten raw as treatment for liver diseases and bad digestion.

Table 2. Continued

Scientific Name	Arabic Name * Common English Name	Status	Traditional uses
Ochradenus aucheri	A.N*: qathb, asa al- jabal, shim		Common
Reseda aucheri	dhaub, zinban	Common	
Ziziphus spina-christi	Sidr, ber, 'ilb, zaqa. Fruit: nabaq, dum		Wood used for making poles and pillar and as fuel.
	* christ's torn, nabk tree	Common	Thorny branches as livestock barrier. Boiled leaves as shampoo, or applied to soften skin. Ash of wood mixed with vinegar applied to snake bites. Tea as a treatment for measles. Flowers important for honey production of wild bees (*Apis florea*)
Lycium shawii	'ausaj, shaaz, qasad, semkis		Stem boiled used as a laxative and diuretic. Leaves
	* Desert thorn	Common	used to treat jaundice. Berries are edible when ripe, to treat colic. In spite of its spines, heavily grazed by livestock, when growing on its own. Often found inter-twined with *Acacia tortilis* trees, where it is not browsed and can grow larger.
Tamarix aphylla = *T. articulata* athl	* tamarisk	Rare	Died powered leaves boiled with water ingested to treat prolonged labour, and to saddle sores and rope burns in animals. Wood resistant to termites and used for construction.
Typha domingensis	barda, nataf	Uncommon	Dried crushed flowers applied to burns for cooling effect.
Fagonia indica	shekka, dhreima, humaylah		Powdered leaves and roots boiled in water taken by
	* fagonia	Common	mouth as a treatment for colic or fever. Whole plant boiled mixed with thyme taken by mouth to treat kidney stones or eye problems.

Table 3. Mammal species recorded in the study area and their international and national conservation status. In grey: species for which the presence in Wadi Wurayah has still to be determined Others: Hornby (1996a), Stuart and Stuart (1996), Sawaf (1999).

Significance of the IUCN Red List criteriae (IUCN 2009): DD: data deficient, LR: lower risk, LC: least concern, NT: near threatened, VU: vulnerable, EN: endangered, CR: critically endangered, EW: extinct in the wild.

Common Name	Scientific Name	**EWS-WWF**	**Others**	IUCN Red List (2009)	UAE Red List (Hornby 1996b)
Brandt's Hedgehog	*Hemiechinus hypomelas*	X	X	LR/lc	LC
Muscat Mouse-tailed Bat	*Rhinopoma muscatellum*	X	X	LR/lc	DD
Naked-rumped Tomb Bat	*Taphozous nudiventris*			LR/lc	DD
Trident Leaf-nosed Bat	*Asellia tridens*			LC	DD
Persian Leaf-nosed Bat	*Triaenops persicus*			LC	DD
Sind Serotine Bat	*Eptesicus nasutus*			VU	DD
Kuhl's Pipistrelle	*Pipistrellus kuhlii*			LC	Not Listed
Hemprich's Long-eared Bat	*Otonycteris hemprichii*			LR/lc	DD
Red Fox	*Vulpes vulpes*	X	X	LC	LC
Blanford's Fox	*Vulpes cana*	X	X	VU	VU
White-tailed Mongoose	*Ichneumia albicauda*			LR/lc	Not Listed

Table 3. Continued

Common Name	Scientific Name	**EWS-WWF**	**Others**	IUCN Red List (2009)	UAE Red List (Hornby 1996b)
Gordon's Wildcat	*Felis silvestris gordoni*	X	X	LC	EN
Caracal Lynx	*Caracal caracal schmitzi*	X	X	LC	VU
Arabian Leopard	*Panthera pardus nimr*	X	X	CR	CR
Arabian Tahr	*Hemitragus jayakari*	X	X	EN	CR
Mountain Gazelle	*Gazella gazella cora*	X	X	VU	VU
Rat unidentified	*Rattus sp.*	X		-	LC
Egyptian Spiny Mouse	*Acomys cahirinus*	X	X	LC	NT
Wagner's Gerbil	*Gerbillus dasyurus*	X		LR/lc	DD
Baluchistan Gerbil	*Gerbillus nanus*			LC	DD

Table 4. Bird species recorded in the study area and their international and national conservation status. In grey: species breeding or suspected breeding in the area. Others: Aspinall (1995, 1996), Hornby (1996a), Stuart and Stuart (1996), Richardson (1997, 2003), Emirates Natural History Groups (personal communication).
Significance of the IUCN Red List criteria (IUCN 2009): CR: critically endangered, DD: data deficient, LC: least concern, NT: near threatened, VU: vulnerable, EN: endangered, EW: extinct in the wild. Significance of the UAE status (Hornby and Aspinall 1996 and Javed 2004): GTN: Globally Threatened (Near Threatened), GTV: Globally Threatened (Vulnerable), GTN: Globally Threatened (Near Threatened) RR: Restricted Range, RI: Regionally Important, ND: Native and Declining

Common Name	Scientific Name	**EWS-WWF**	**Others**	IUCN Red List (2009)	UAE Red List (Hornby 1996b)
Little Grebe	*Tachybaptus ruficollis*	X	X	LC	
Little Bittern	*Ixobrychus minutus*	X		LC	
Grey Heron	*Ardea cinerea*	X		LC	
Common Teal	*Anas crecca*	X		LC	
Mallard	*Anas platyrhynchos*	X		LC	
Egyptian Vulture	*Neophron percnopterus*		X	EN	RT
Griffon Vulture	*Gyps fulvus*		X	LC	
Lappet faced Vulture	*Torgos tracheliotos*		X	VU	GTV
Short toed Eagle	*Circaetus gallicus*		X	LC	
Eurasian Sparrowhawk	*Accipiter nisus*	X	X	LC	
Long-legged Buzzard	*Buteo rufinus*	X		LC	
Bonelli's Eagle	*Hieraaetus fasciatus*	X	X	LC	ND
Lesser Kestrel	*Falco naumanni*		X	VU	GTV
Kestrel *Falco tinnunculus*	X	X	LC		
Barbary Falcon	*Falco pelegrinoides*		X	LC	ND
Chukar *Alectoris chukar*		X	LC		
Sand Partridge	*Ammoperdix heyi*	X	X	LC	RR
Grey Francolin	*Francolinus pondicerianus*	X	X	LC	
Coot	*Fulica atra*	X		LC	
Asian Houbara Bustard	*Chlamydotis macqueeni*	X		VU	GTN
Black winged Stilt	*Himantopus himantopus*	X		LC	RI
Red-wattled Lapwing	*Vanellus indicus*	X		LC	
Green Sandpiper	*Tringa ochropus*	X		LC	

Table 4. Continued.

Common Name	Scientific Name	EWS-WWF	Others	IUCN Red List (2009)	UAE Red List (Hornby 1996b)
Lichtenstein's Sandgrouse	*Pterocles lichtensteinii*	X	X	LC	
Rock Dove	*Columba livia*	X	X	LC	
Collared Dove	*Streptopelia decaocto*	X	X	LC	
European Turtle Dove	*Streptopelia turtur*		X	LC	
Laughing Dove	*Streptopelia senegalensis*	X	X	LC	
Hume's Tawny Owl	*Strix butleri*	X		LC	
Desert Eagle Owl	*Bubo ascalaphus*	X?	X	LC	ND
Spotted Eagle Owl	*Bubo africanus*	X?	X	LC	
Little Owl	*Athene noctua*	X	X	LC	
Common Swift	*Apus apus*	X		LC	
Pallid Swift	*Apus pallidus*	X		LC	
Common Kingfisher	*Alcedo atthis*	X	X	LC	
Little Green Bee-eater	*Merops orientalis*	X	X	LC	
Indian Roller	*Coracias benghalensis*	X	X	LC	
Eurasian Hoopoe	*Upupa epops*	X		LC	
Desert Lark	*Ammomanes deserti*	X	X	LC	
Crested Lark	*Galerida cristata*	X	X	LC	
African Rock Martin	*Ptyonoprogne fuligula*	X		LC	
Pale Crag Martin	*Hirundo obsoleta*		X	LC	
Barn Swallow	*Hirundo rustica*	X		LC	
Long-billed Pipit	*Anthus similis*	X	X	LC	
Yellow Wagtail	*Motacilla flava*	X		LC	
Grey Wagtail	*Motacilla cinerea*	X	X	LC	
Yellow-vented Bulbul	*Pycnonotus xanthopygos*	X	X	LC	RR
Black Redstart	*Phoenicurus ochruros*	X		LC	
Rufous-tailed Wheatear	*Oenanthe xanthoprymna*	X	X	LC	RR
Variable Wheatear	*Oenanthe picata*		X	LC	
Mourning Wheatear	*Oenanthe lugens*	X		LC	
Hooded Wheatear	*Oenanthe monacha*	X		LC	RR
Hume's Wheatear	*Oenanthe albonigra*	X	X	LC	RR
Rufous –Tailed Rock-Thrush	*Monticola saxatilis*	X		LC	
Blue Rock Thrush	*Monticola solitarius*	X		LC	
Graceful Warbler	*Prinia gracilis*	X	X	LC	
Scrub Warbler	*Scotocerca inquieta*	X	X	LC	
Upcher's Warbler	*Hippolais languida*		X	LC	RR
Menetries' Warbler	*Sylvia mystacea*	X	X	LC	RR
Desert Lesser Whitethroat	*Sylvia minula*		X	LC	RR
Plain Leaf Warbler	*Phylloscopus neglectus*		X	LC	RR
Arabian Babbler	*Turdoides squamiceps*	X	X	LC	RR
Purple Sunbird	*Nectarinia asiatica*	X	X	LC	
Southern Grey Shrike	*Lanius meridionalis*	X	X	LC	
Steppe Grey Shrike	*Lanius pallidirostris*		X	LC	
House Crow	*Corvus splendens*	X		LC	
Brown-necked Raven	*Corvus ruficollis*	X	X	LC	
Common Mynah	*Acridotheres tristis*	X	X	LC	
House Sparrow	*Passer domesticus*	X	X	LC	
Pale Rock Sparrow	*Petronia brachydactyla*		X	LC	
Chestnut-shouldered Petronia	*Petronia xanthocollis*		X	LC	
White-throated Munia	*Lonchura malabarica*	X	X	LC	
House Bunting	*Emberiza striolata*	X	X	LC	

Table 5. Reptile species recorded in the study area and their international and national conservation status. In grey: species endemic to Northern Oman-UAE. In bold: species endemic to Arabian Peninsula. Others: Hornby (1996a), Stuart and Stuart (1996), Segan (personal commun.), and Gardner (personal commun.). Significance of the IUCN Red List criteria (IUCN 2009): CR: critically endangered, DD: data deficient, LC: least concern, NT: near threatened, VU: vulnerable, EN: endangered, EW: extinct in the wild.

Sinai Agama	*Pseudotrapelus sinaitus*	X	X	Not Listed
Bar-tailed Semaphore Gecko	*Pristurus celerrimus*	X	X	Not Listed
Rock semaphore Gecko	*Pristurus rupestris*	X	X	Not Listed
Fan-footed Gecko	*Ptyodactylus hasselquistii*	X	X	Not Listed
Banded ground Gecko	*Bunopus spatalurus hajarensis*	X	X	Not Listed
House Gecko	*Hemidactylus sp.*		X	Not Listed
Blue-tailed Oman Lizard	*Omanosaura cyanura*	X	X	Not Listed
Jayakar's Oman Lizard	*Omanosaura jayakari*	X	X	Not Listed
Tessellated Mabuya	*Mabuya tessellata*	X	X	Not Listed
Ocellated Skink	*Chalcides ocellatus ocellatus*	X	-	Not Listed
Wadi Racer	*Platyceps rhodorachis*	X	X	Not Listed
Schokari Sand Racer	*Psammophis schokari*		X	Not Listed
Sind Saw-scaled Viper	*Echis carinatus sochureki*		X	Not Listed
Oman Saw-scaled Viper	*Echis omanensis*	X	X	Not Listed
Arabian Toad	*Bufo arabicus*	**X**	**X**	**LC**
Dhofar Toad	*Bufo dhufarensis*	**X**	**X**	**LC**
Red-eared Slider	*Trachemys scripta*	X	-	NT

the Egyptian Vulture (*Neophron percnopterus*), Bonelli's Eagle (*Hieraaetus fasciatus*), and the Barbary Falcon (*Falco pelegrinoides*) which are native and declining (Hornby and Aspinall 1996, Hellyer and Aspinall 2005). Down-stream near the coast, House Sparrows (*Passer domesticus*), Laughing Doves (*Streptopelia senegalensis*), Grey Francolins (*Francolinus pondicerianus*), Little Green Bee-eaters (*Merops orientalis*), Indian Roller (*Coracias benghalensis*), Purple Sunbirds, and Southern Grey Shrikes (*Lanius meridionalis*) are breeding in and around farms and gardens that also attract many migrant species during the spring and autumn.

A total of 14 species of reptiles and amphibians on the 17 suspected to occur in the area have been recorded by the survey team (Table 5). Stuart and Stuart (1996) recorded the Sind Saw-scaled Viper (*Echis carinatus sochureki*) in the area. However, the *Echis* complex in Arabian Peninsula has been revised recently with the identification of a new species: the Omani Carpet Viper (*Echis omanensis*) that is restricted to the Hajar Mountains range (Babocsay 2004, Egan 2007, Gardner 2008). The most common species of reptiles found during the day within the Wadi Wurayah region were the Sinai Agama (*Pseudotrapelus sinaitus*), the Rock Semaphore Gecko (*Pristurus rupestris*), the Wadi Racer (*Platyceps rhodorhacis*) and the Omani Carpet Viper. The two species of amphibians occurring in UAE were found: the Arabian Toad (*Bufo arabicus*) and the Dhofar Toad (*Bufo dhufarensis*), with a new confirmed record for this species in the area. It is worthy to note that Wadi Wurayah hosts five species that are endemic to mountains of UAE and northern Oman: Blue-tailed Lizard (*Omanosaura cyanura*), Bar-tailed Semaphore Gecko, Banded ground Gecko (*Bunopus spatalurus hajarensis*) and Omani Carpet Viper (Hornby 1996a, Hellyer and Aspinall 2005, Egan 2007, Gardner 2008).

There are just 17 native species of primary freshwater fishes found throughout the entire Arabian Peninsula- primary being completely dependant on the presence of permanent freshwater. Two of these species are found in Eastern and Southern parts of the UAE and in Northern Oman; *Garra barreimiae* and *Cyprinion microphthalmum muscatensis*. The Northern limit for *Cyprinion microphthalmum muscatensis* is in the locality of the UAE/Oman border (Feulner 1998). *Garra barreimiae* is the only native fish species present in Wadi Wurayah.

A total of 74 terrestrial invertebrate families have been identified so far, belonging to 12 different orders (Figure 3). Many more species have been collected and

remain to be identified, such as Odonata (dragonflies) and Lepidoptera (butterflies and moths) specimens that were sent for examination by specialists worldwide. So far, Diptera (flies), Hymenoptera (wasp, bees) and Coleoptera (beetles) represented the most diverse order of invertebrates in Wadi Wurayah with 25, 21 and 15 families respectively. Aquatic invertebrates: Coleoptera(beetles), Hemiptera (bugs), Odonata (dragonflies), Trichoptera (caddisflies), Platyhelminthes (flatworms), Nematodes (roundworms), Annelids (segmented worms), and Gastropoda (molluscs) were collected during the aquatic survey of permanent water pools. Due to its habitats diversity and the presence of permanent water, Wadi Wurayah can be considered a stronghold for the invertebrate fauna in UAE. Nineteen species of arthropods new for science have been discovered in Wadi Wurayah, of which 12 have been described for the first time in the wadi (Table 6). Five of these new species are Ephemeroptera (mayflies), which are water-dependent for most of their life as larvae, very pollution sensitive and are used as indicators of good-water quality worldwide. (van Harthen 2008, 2009).

ANCIENT AND CURRENT USE

When not mentioned, the following information is extracted from the following sources: Brook (2006), EWS-WWF (2006), Sawaf (2006b).

Archaeological Significance

The Fujairah Emirate is very rich in archaeological and historical sites of national and international importance (Hellyer 1989, Hellyer 1990, Hellyer 1993, Hornby 1996b, Ziolkowski 1998a, Ziolkowski 1998b, Ziolkowski 2002, Brass et *al.* 2005). Prehistoric burials were found and excavated in Wadi Saqamqam, north of Fujairah town, and important petroglyph sites were described south-southwest Fujairah town (Wadi Al-Hayl, Wadi Saham, Wadi ah-Shanah), southwest Dibba (Hassat al-Risoom) and Dadnah. Old settlements from the Third Millennium BC (3000 BC) were found in the vicinity of the Wadi Wurayah Protected Area and in Bidiyah (stone-walled buildings). Long collective graves from the Second Millennium BC have been discovered in Bidiyah (al-Tikriti 1989).

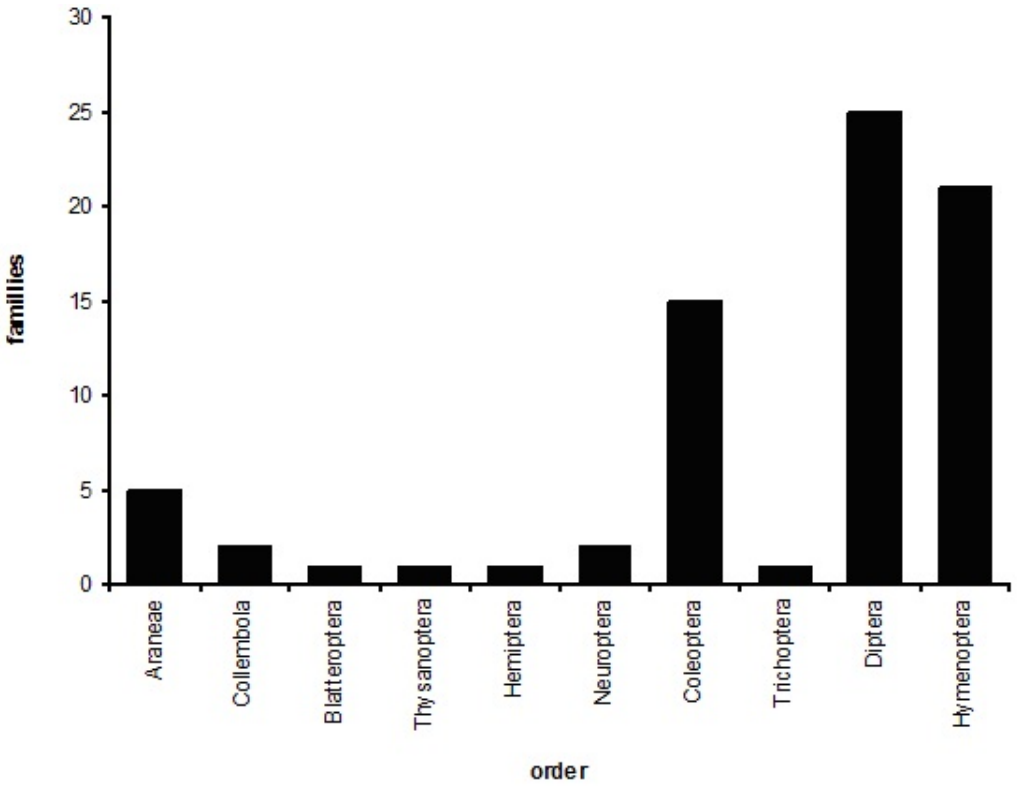

Figure 3. Terrestrial invertebrates families identified so far in Wadi Wurayah, Fujairah, UAE.

Table 6. New species of arthropods for science discovered in the study area. Species highlighted in grey have been described for the first time in Wadi Wurayah Protected Area (from van Harten 2008 & 2009)

Class	Subclass	Order	Family	species
Entognatha	Collembola	Entomobryomorpha	Entomobryidae	*Seira infrequens*
Insecta	Pterygota	Coleoptera	Georissidae	*Georissus chameleon*
			Dermestidae	*Attagenus papei*
			Anthicidae	*Striticollis desoatius*
			Curculionidae	*Rhampus micros*
		Diptera	Tephritidae	*Oxyaciura nigra*
			Scenopinidae	*Scenopinus megapodemus*
			Psychodidae	*Limomornia wadi*
		Ephemeroptera	Baetidae	*Nigrobaetis arabiensis*
				Cheleocloreon soldani
				Cloeon arenorum
			Leptophlebiidae	*Choroterpes (Choroterpes) pacis*
			Caenidae	*Caenis malzacheri*
		Hymenoptera	Platygastridae	*Amblyaspis harteni*
				Platygaster papei
				Synopeas ubiquitosus
				Synopeas scutoscutellaris
			Chrysididae	*Chrysis harteni*
		Pscocoptera	Psocidae	*Arabopsocus siniproctus*

A number of sites from the Iron Age (1,300-500 BC) were identified near Wadi Wurayah Protected Area in the mountains (Bithna, Wadi Asimah, and Wadi Awhalla) and on the coast (Dibba and Qidfa). The most ancient mosque of the UAE dating from 1450 to 1670 AD is located in Bidiyah (Ziolkowski 2008). Forts dating from 16th to 19th century can be found in Fujairah, Bithnah, Al Hayl and Awhala.

So far, 24 old settlements, two Islamic graveyards, two pre-Islamic tombs and one petroglyphs (rock carving) site were identified in the Wadi Wurayah catchment basin. Porcelain and pottery fragments from15th to 18th centuries AD were also found (Ziolkowski 2007). Two cairn sites were also discovered in the north part of the surveyed area and their significance remains to be verified. The two pre-Islamic tombs, some of them similar to examples found all over the East Coast (including the Wadi Saqamqam graves; Ziolkowski 2003), on the plain of Kalba (~60 graves) seem to be of a Late Pre-Islamic date (ie post 300 BC to ca 6th century AD). However, since an extensive settlement continued without interruption for several thousand years until recent times (according to locals, the last bedu family to camp during winter in Wadi Wurayah left the area in 1981), it is difficult to date the sites discovered in Wadi Wurayah area with precision without further archaeological investigations and proper excavations.

Agriculture

Until the 1970s, like most of the areas of the Hajar Mountains, goats were the main domestic livestock used for milk, meat and skins. Donkeys were used as beast of burden until the availability of four-wheel drive vehicles. Within the in the Wadi Wurayah catchment basin, there are no more goat camps, even during the winter; their presence stopped in 1981. Nevertheless, goat presence (tracks, faeces or sightings) was recorded in all of the Wadi Wurayah area surveyed. Goats observed in Wadi Wurayah are now feral and are not owned by anyone. Even though the area had some permanent settlements in the past, the majority of its residents used to migrate between the mountain area and the coastal area where they were spending the hottest season (April-October) trading, looking after their palm plantations, and fishing. Presence of permanent water resources in Wadi

Wurayah has allowed a light variety of agriculture (mostly date palm cultivation), as the presence of abandoned oases within the surveyed area shows. The agricultural activities, mostly dates, mango (*Mangifera sp.*) and *Citrus sp.* trees, are nowadays concentrated in the down-stream part of the wadi, near the coast. Nevertheless, Wadi Wurayah has been, and continues to be, used by local inhabitants from Masafi and Bidiyah for wild honey gathering. Starting in May, honey gatherers search for wild honey comb from wild bees (*Apis florea*) in crevices and caves that they will collect in autumn. The quality of honey is said to be exceptionally good. This honey is therefore not sold in the open market, as the gatherers and purchasers know each other and deals are done in private. Honey gatherers have generally their production sold even before collection. Some of this production is given to dignitaries rather than sold. The local honey gathering corporation is ruled by ancestral codes such as "*the first person to find a honey comb in spring marks the site with his proper sign or code (stone pile, rock carving, and/or branches) and nobody touches it*". Locals complain that foreigners do not respect these rules. Due to the high revenues provided by the wild honey sale (ca 150 USD for a 75cl bottle), this activity generates a lot of interest and, according to locals, has become more intensive during the years with the competition of foreigners and the accessibility to the site due to a tarmac road that leads to the waterfall. Honey gatherers represent only 5.3% of the local people interviewed during the social survey.

Water Extraction

Compared to other parts of the country, there is little ground water extraction within Wadi Wurayah. Water resources development within the catchment is currently restricted to the down stream part of the catchment basin for agriculture, and municipal well fields supplying the main towns of Khor Fakkan and Bidiyah and a bottled water factory near Bidiyah. However, because of gravity and topography, any deterioration of the general water situation in the lower catchment and coastal plain can never have a hydrological impact on either the surface or groundwater resources of the mid-upper catchment. A small dam has been constructed upstream of the main waterfall to divert surface flow into a 3 m diameter concrete caisson which then feeds by gravity into a 25-cm HDPE pipeline down wadi to the area of agriculture. However, the system installed some 15-20 years ago and destroyed by the successive floods, is now abandoned.

Some 114 recharge dams have been constructed in the Northern Emirates since the 1980's, with a combined capacity of 114 Mm^3. The dams serve the dual purpose of preventing downstream flooding (often causing severe damage to roads, buildings etc. and also interruptions to road traffic) and enhancing the recharge to aquifers by storing the runoff so that it can be gradually released downstream for maximum recharge effectiveness. A dam was constructed in 1997 in the lower part of Wadi Al Wurayah and is one of the largest dams built in the region (Figure 4). From 1997 to 2005, a total of nearly 9 Mm^3 was captured from flood events. Downstream, there are three breaker dam walls to capture the main dam overflows, at 2.5 km, 8 km and 10.5 km downstream of the main dam. Both the downstream agricultural development and the domestic municipal well fields supplying Khor Fakkan and Bidiyah have benefited from the dam and breakers. Observation wells were drilled by the UAE Ministry of Agriculture and Fisheries at the same time as completion of the Al Wurayah recharge dam to monitor the groundwater levels.

Tourism

Until now, despite its popular attraction, there are no tourism facilities in Wadi Wurayah. Locals, residents and tourists visit Wurayah for its permanent waterfalls and the beauty of the scenery, mostly during the weekend for a daily visit or an evening picnic. The access has been considerably facilitated during the last 10 years by the construction of a tarmac road in 1996 that leads to the dam and the main waterfall. The tarmac road ends with a parking lot situated above the main waterfall and tourists can climb down to the waterfall.

IDENTIFIED THREATS

Overgrazing

The Wadi Wurayah area is no longer exploited by goat herders. Since the 1990s, they keep their herds in fenced farms where they can be supplied better quality food at lower costs. However, there are still remnant populations of domestic goats and donkeys which have become feral over time. These feral species can pose problems to the freshwater environments; goats frequently defecate in water bodies, increasing ammonia and nitrate levels, and colliformes pollution (Knuteson 2008). Goats graze vegetation indiscriminately, unlike

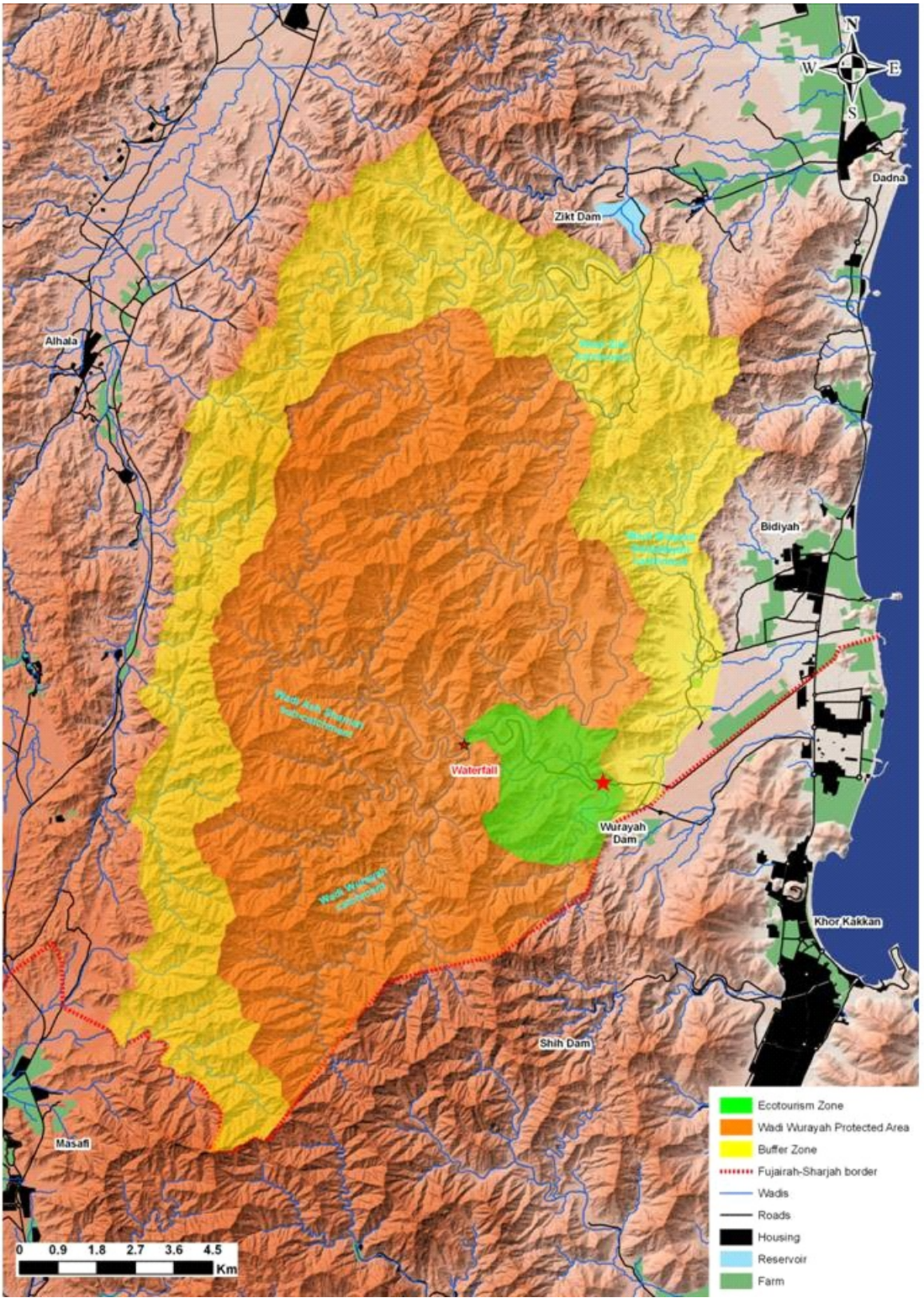

Figure 4. The Wadi Wurayah Protected Area with its extension. The main tourist attraction (waterfall) is indicated with a star.

the more selective Mountain Gazelle and Arabian Tahr. As a result certain plant species decrease which may be important food sources for native wildlife. Combined with drought and the disappearance of the potential predators (Arabian Leopard, Caracal) due to human persecution, grazing by domestic and feral livestock threatens the native vegetation. Should this combination of stresses on the environment continue, the vegetation may not recover, ultimately leading to the total extirpation of the native flora, and the disappearance of the endemic herbivore fauna (Arabian Thar, Mountain Gazelle, gerbils, birds, insects) and their predators (Arabian Leopard, Caracal, Blanford's Fox, Gordon's Wild Cat, raptors, etc.). Despite their impact on the vegetation, feral goats have now became part of the diet of the Arabian Leopards and Caracals, as observed. Feral goat populations might have reached an equilibrium in relation with predators, climate and water availability. However, the decline of predators due to human persecution might have allowed the population of feral goats to increase and the problem of overgrazing to arise. Feral donkeys in Wadi Wurayah are not considered a threat since their number is low (estimated to less than 5 individuals) and concentrate in the lower parts of the surveyed area.

Water overexploitation

Historically, UAE's water requirements were met solely from groundwater obtained from shallow hand dug wells and in the mountainous areas: the traditional "*falaj*" system, man-made channels used to collect groundwater, spring water and surface water and transport it, by gravity, to a demand area. Over the last 30 years, however, rapid economic development, coupled with sharp population increases and the development of large agricultural and forestry sectors, substantially supported from Government subsidies, has meant an increasing pressure on the existing water resources. In Al Ain region, Abu Dhabi Emirate, a groundwater level loss of 61 to 93m in 10 years has been observed (Brook *et al.* 2006). In mountainous areas, the *falaj* system has been replaced by the construction of dams. Groundwater extraction within the vicinity of plantations also cause die-off of natural vegetation in lower lying areas and the intrusion of sea-salt water at the coast results in the salinisation of water resources and soils. However, as mentioned above, because of the topography, the deterioration of the water situation in the lower catchment and coastal plain of Wadi Wurayah can never have an hydrological impact on the surface and groundwater resources of the mid-upper catchment. Therefore the perennial surface waters of Wadi Wurayah, which make it a unique place in the UAE with a rich and varied biodiversity, are safeguarded against any over-exploitation of water resources in the lower parts of the same catchment. Dam reservoirs may controversially provide additional habitats that may be colonized by aquatic vegetation, invertebrates, amphibians, fish, etc. As an example, Rufaysah dam of Wadi Shi in the south of our study area (Figure 4), near Kohr Fakkan (Sharjah Emirate), became one of the wetlands of international importance in UAE and is one of the few breeding sites in the UAE for the Little Grebe (*Tachybaptus ruficollis*). It is also a hosting site for migrating and wintering birds (Aspinall 1995. It is also believed to attract Wadi Wurayah wildlife that crosses mountain passes to come to drink. However, in arid lands, permanent water pools are a local tourist attraction and are heavily frequented during week-ends. As a result, the sites are often degraded with litter deposits, fires and vehicle tracks. Unlike Wadi Shih Reservoir, most of the reservoirs such as Wurayah, in the region are dry and construction involved in dam production has had a heavy impact on habitats and wildlife, due to the process of taking material for the dams and accessing roads which cause disturbance by people and vehicles in the area.

Mining

In 2005, there were 64 crushers in the Fujairah Emirate alone, representing 40% of the labour force and income of the emirate (Fujairah Statistics Yearbook 2006). Crushing and quarries for mineral extraction not only mean an irreversible loss of habitat, but also induces a supplementary stress to the remnant arid mountain fragile wildlife populations, weakened by natural causes (drought), overhunting in the past, poaching, water extraction for agriculture, habitat fragmentation with development, interspecific competition with livestock and feral goats for food and water. So far, Wadi Wurayah has been spared by the mining activities. However, abandoned quarries at the parking lot above the main waterfall and in Wadi Shi to the south and Wadi Zikt to the north of the area show that the region was prospected for construction material production. If planned, the development of crushers, the construction of infrastructure (buildings, roads, etc.) and the nuisance (traffic, dust, noise) associated with it, will have a severe and irremediable impact on

the site. To our knowledge, there are no current projects of quarries in the area.

Habitat Fragmentation and Urbanisation

Agricultural and urbanised lands into the eastern part-downstream of Wadi Wurayah Protected Area have been extending. A road is currently being built south of the catchment basin between Khor Fakkan and Masafi. However, the impact on the pristine habitat upstream is until now negligible, with the exception of the incursion of Feral Cats (*Felis cattus*) and Feral Dogs (*Canis canis*) from the suburbs of Bidiyah town, and the trapping/poisoning of wild carnivores that are attracted by domestic livestock and garbage. A large scale development project with permanent settlement and the construction of infrastructure associated with it (buildings, roads, etc.) within the catchment basin has been proposed and was fortunately abandoned. This would have had a severe impact on the site, the beauty of the scenery, and certainly the integrity of this environment. A secondary consequence of permanent development will be the continuous presence of people at the site, the risk of more rubbish and pollution deposited and the attraction of feral animals (goats, dogs and cats). If development has to be done in the area, decision makers must ensure that the developers respect the environment through, for example, architecture integrated in the landscape with the use of traditional material and techniques, and that mitigation measures are implemented to prevent irremediable damages and pollution.

Wildlife Poaching and Persecution

Despite the UAE Federal Law N° 24 of 1999 updated in 2006, hunting and poaching still occur in Wadi Wurayah area. However, exact figures are difficult to assess. On the basis of our social survey, official declared hunters were only 12 (= 8 % of the people interviewed) of which only two men admitted to still hunt today (mostly feral goats, Arabian Tahr, Mountain Gazelle, Sand Partridge). Honey collectors may often carry a gun and at the occasion, shoot what they encounter. Bidiyah residents accuse Masafi residents, and vice versa, to come to poach tahrs and gazelles in Wadi Wurayah. Hunting and poaching by non-residents is suspected also. Hunting activity is higher during late spring and summer which is the period when wildlife visit the permanent water sources and is more predictable and vulnerable. Because of their potential threat to domestic livestock, caracals, foxes and the elusive Arabian leopard are subject to persecution in the whole region and still trapped, poisoned or shot. A Bonelli Eagle with strings was observed in the study area. According to falconers, local Asian workers expect to ameliorate their revenue by trapping any raptor species and trying to sell them to local falconers. Since the species is not favourable for falconry, the Bonelli Eagle was probably mistaken for a falcon, refused by the falconer and released by the trapper who could not sell it.

Habitat Degradation

As a consequence of the construction of the tarmac road in 1996 and the citation of the site in UAE tourist and off-road guides, the site has increasingly gained considerable recognition and has therefore been considerably degraded with tagging (painting) of the rocks, continuous and widespread litter deposits and burning of native vegetation during the last couple of years. A large input of organic items of rubbish, including food and sewage, can increase nitrates and phosphates in the water therefore increasing algae and leading to eutrophic conditions, a decrease in Dissolved Oxygen and the extirpation of the unique aquatic fauna. Knuteson (2008) showed that the wadis waters in the region have been infected by the colliformes from animal faeces origin but also *Escherichia coli* from human faeces origin. Recent samplings in Wadi Wurayah show also the presence of these bacteriae in the pools visited by tourists (Knuteson unpublished). Litter deposit and left-over by tourists also attracts and allows the colonisation and survival of feral animals such as goats, donkeys, cats and dogs, and Red Foxes as well, that compete with or predate on indigenous wildlife. Graffiti is prevalent around the main waterfall pool, although this is predominantly an aesthetic problem; the aerosol paints used are toxic and usually discarded in the area when empty. Despite the heavy tourist pressure on the site, few people overnight or go beyond the two spots that can be reached by four wheel drives, due to the strong fear of snakes. Honey collectors and hunters frequently put fire to the vegetation in the wadi, either to clear and facilitate the access or to kill snakes. This activity is considerably prejudicial to the natural flora and fauna but also the beauty and scenery.

Introduced Species

Since their introduction from Iran in the 16th century by the Portuguese, Chukar (*Alectoris chukar*) populations have been remaining in the mountains of UAE and reinforced by continuous introductions, especially during the last decades (Aspinall 1996). Chuckars have been reported in the Masafi area and may occur occasionally on the western side of the Wadi Wurayah as well. This species, as the indigenous Sand Partridge, is now part of the diet of the Arabian Leopard and Caracal. However, in November 2007, a Red-eared Slider turtle, (*Trachemys scripta*), has been discovered in a pool of Wadi Wurayah. The faeces analysis of the Red-eared Slider *in-situ* revealed the presence of wadifish, aquatic invertebrates including mollusks, and algae. Originated from the New World, this species has been introduced in the wild in the World through pet trade. Because of its aggressiveness and outcompeting with natives turtles species, its impact on the native fauna and flora and being a vector of diseases, especially *Salmonella* sp., to the native fauna and humans, the Red-eared Slider has been nominated as one of the 100 "World's Worst" invaders by the Invasive Species Specialist Group of the IUCN; http://www.issg.org/database. The closest established feral population of Red-eared Slider in the Arabian Peninsula is found in Bahrain, where it replaced the native (or long time ago introduced) *Mauremys caspica* (Gasparetti et al. 1993). Some reports however indicate the presence of Red-eared Sliders in UAE: recently in a pond at the Zayed University in Abu Dhabi (D. Gardner, pers. com.), a large quarry hole in gravels in Ras al Khaimah (from more than a decade ago, now gone). The observations of recent specimens in a wadi in the Madam-Hatta area (G. Faulner, pers. com.), Rufaysah dam of Wadi Shi (G. Faulner, pers. com.) and in Wadi Wurayah are extremely worrying.

Cichlid fish species such as *Tilapia sp.* and *Oreochromis* are frequently introduced throughout the Arabian Peninsula for food, sport and mosquito control and affects native species via predation or competition for habitat and food resources. If absent in Wadi Wurayah, Tilapia fish are present in the nearby Rufaysah reservoir of Wadi Shi and remains a constant threat. As mentioned above, feral species constitute also a constant pressure on the Wadi Wurayah ecosystems. However, in addition to be vectors of diseases such as feline immunodeficiency lentivirus, or leukaemia (Ostrowski et al. 2003), feral cats compete and interbreed with the rare Gordon's Wildcat (*Felis silvestris gordoni*) to a point that nowadays, the Gordon's Wildcat wild population in the UAE might be not genetically pure anymore and extinct (Tourenq and Drew 2005).

Military Manoeuvres

Military training occurs in the southern border of the Protected Area. Although manoeuvres do not occur irregularly, direct physical disturbance from live-firing exercises, *i.e.* smoke, flares, explosions and the noise associated with them can disturb wildlife. In the vicinity of Bidiyah, there is a military shooting and practicing area. Nevertheless, the activity occurs currently outside of the main interest area and therefore it poses no immediate threat to the Protected Area. Indeed, because of the proximity to the military areas, it is quite possible that large-scale infrastructure development would not be allowed to take place and human incursions would be limited as a result of military security requirements.

CONCLUSIONS

Compared to the UAE fauna and flora, the area hosts ca 44% of the terrestrial plants (ca 300 on 688), 42% of the terrestrial mammals (20 on 48), 24 % of the terrestrial reptiles (13 on 53), 17 % of the birds (74 on 435) and the only two amphibians species recorded for the country (this study, Tourenq and Launay 2008). And new discoveries are expected. Nocturnal species such as owls, bats, rodents and reptiles might be underrepresented in our surveys. In April 2006, an Eagle Owl (*Bubo sp.*) was heard downstream the wadi and the rare and of conservation interest Spotted Eagle Owl (*Bubo africanus*) and the Desert Eagle Owl (*Bubo ascalaphus*) have been spotted by previous authors in the vicinity of the Protected Area. The presence of the Cat Snake (*Telescopus dhara*), so far not recorded in the area, has to be prospected since wild populations are suspected in UAE, but until now without any authenticated record for the country (Gardner, pers. com.). So far 19 new insect species for science have been discovered and more are currently being described and others may to come (van Harthen, pers. com.).
This peculiar wildlife from national and international conservation concern with flagship species, such as the Arabian Thar, the wadi fish *Garra barreimiae* and the orchid *Epipactis veratrifolia,* survive only because of permanent presence of freshwater that makes Wadi

Wurayah natural heritage unique to the country, the Arabian Peninsula and the World. From a conservation of biodiversity prospective, the Wadi Wurayah catchment basin is therefore a remarkable candidate for the creation of a Protected Area that should lead to the effective protection of the last of the natural freshwater habitats in the country. From a cultural prospective, the presence of the 15 old settlements, two Islamic graveyards, two pre-Islamic tombs and one petroglyphs site as well as ancient porcelain and pottery fragments in the Wadi Wurayah catchment basin shows the link with the rich ancient heritage of the Fujairah Emirate. Some of our findings may be of national and international archaeological and historical importance. Wadi Wurayah has therefore a tremendous potential for further archaeological investigation, exhibition and conservation of national cultural heritage.

To our knowledge, there are no current or proposed long-term industrial developments within the Protected Area. The main threats identified in order of importance were overgrazing, water overexploitation, mining, habitat fragmentation and urbanisation, poaching and persecution, habitat degradation, and introduction of non native species. With the perspective of the end of oil and gas reserves, the United Arab Emirates are making tremendous efforts in diversifying their economy. One of the chosen options of diversification is the development of tourism. However, under the lead of Dubai Emirate, the current privileged choice has been the mass tourism, with all of its negative environmental consequences, one of them being an unplanned coastal development. Between 1970 and 1985, Dubai city increased in size from 18 km^2 to 110 km^2 but this rate jumped dramatically during the 2000's and now the whole 60 km coastline of Dubai Emirate is urbanised. About 70% of the UAE coastline has been reclaimed since 1990 (UAE Yearbook 2006, EWS-WWF, unpublished). The more traditional and mountainous Emirates should seek alternatives that would preserve their environment and respect the traditional lifestyles of the local commu-nities. It is of paramount importance for the region that an alternative path to the development of mass tourism observed on the coasts, be explored and demonstrated to assist local governments in protecting and conserving their unique natural heritage and lifestyle.

Since their creation in 1971, the UAE have launched several local and national initiatives concerning environment issues. The country has ratified and accessed to numerous regional and international conventions and protocols on environment protection, including the on Convention Biological Diversity (CBD), (Tourenq and Launay 2008). The CBD Programme of Work on Protected Areas aims, by 2010 (for terrestrial ecosystems) and 2012 (for marine), to establish: "*comprehensive, effectively managed and ecologically-representative national systems of protected areas*" (Secretariat of the Convention on Biological Diversity 1993).

Based on our findings and since its water resources depend on the draining of all the Wadi Wurayah catchment area, the Wadi Wurayah Protected Area matches with the limits of upper part of the catchment area and the boundary between Fujairah and Sharjah emirates. The surface of the Protected Area is 113 km^2. Because of the evidence of movements of wildlife to and from, upstream parts of Wadi May, Wadi Zikt, Wadi Maqsad-Swaideiyah catchments have been included in the Protected Area as "buffer zone". With this extension, the total surface of the Protected Area is 231 km^2 (Figure 4). This project, a.k.a. the collaboration between a local NGO, a local government with the support of the private sector, is the first of its kind in the UAE, and an example for other Emirates integrating tourism, local use and conservation of unique natural resources. The main objective of Wadi Wurayah Protected Area are to establish a sustainable protected area integrating local tradition and lifestyle with the conservation of inimitable biodiversity and habitat by providing a model of unique economical incentives to the region. Wadi Wurayah Protected Area would belong to the Protected Areas Category II of the World Conservation for Nature (IUCN 1994): *"Protected area managed mainly for ecosystem protection and recreation (e.g. National Park)"*.

Therefore, the Wadi Wurayah Protected Area management must ensure:

1. To protect the ecological integrity of the freshwater ecosystem for present and future generations,
2. To exclude exploitation or occupation unfriendly to the purposes of designation of the area,
3. To provide a foundation for scientific, educational, recreational and visitor opportunities, all of which must be environmentally and culturally compatible.
4. To reach the objectives of the Wadi Wurayah Protected Area, the management plan has the following main objectives:
5. To ensure the protection of the Wurayah freshwater catchment area of national and international significance for scientific, educational, recreational or tourist purposes,

6. To perpetuate, in as natural a state as possible, representative examples of physiographic regions, biotic communities, genetic resources, and species, to provide ecological stability and diversity,
7. To manage visitor use for educational, cultural and recreational purposes at a level which will maintain the area in a natural or near natural state,
8. To eliminate and thereafter prevent exploitations or occupations incompatible with to the purposes of the designation of the Protected Area,
9. To maintain respect for the ecological, geomorphologic, sacred or aesthetic attributes which warranted designation of the Protected Area,
10. To take into account the needs of local people, including subsistence resource use, in so far as these will not adversely affect the other objectives of management

Because of its permanent freshwater sources and unique natural and cultural heritage, Wadi Wurayah Protected Area was proposed as a UAE RAMSAR site in summer 2009. The Ramsar Convention, ratified by UAE in 2007, is named after Ramsar, Iran, where in 1971, was signed an intergovernmental treaty which provides the framework for national action and international cooperation for the conservation and wise use of wetlands and their resources. Although the RAMSAR listing doesn't ensure a protection, it elevates the site to a higher status (= recognized as a place of "international importance") and focuses more attention upon it. National governments are then implicitly making a commitment to ensure that the ecological character of the site will be maintained (Ramsar Convention Secretariat 2006).

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