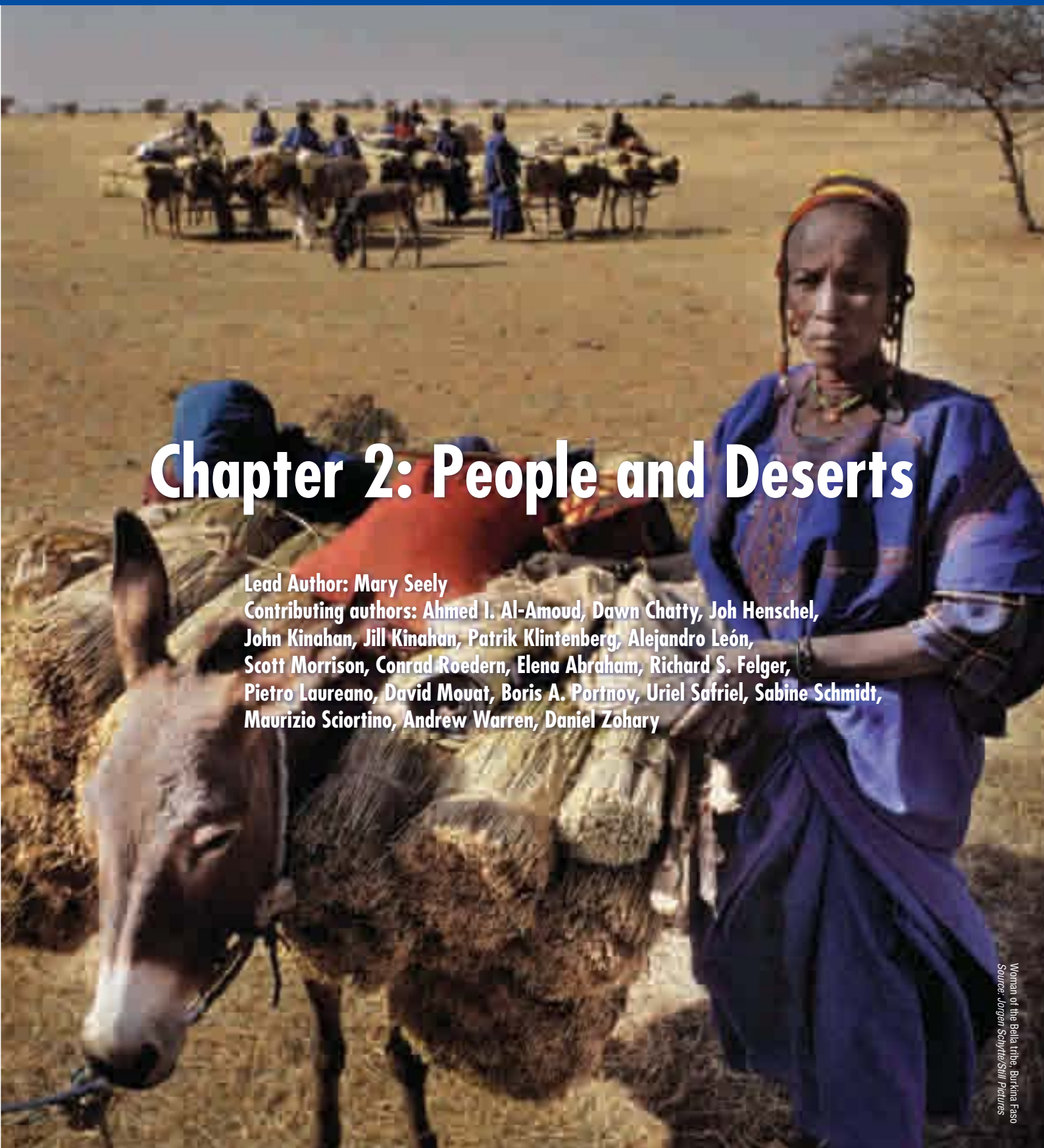
2

Chapter 2: People and Deserts

Lead Author: Mary Seely
Contributing authors: Ahmed I. Al-Amoud, Dawn Chatty, Joh Henschel, John Kinahan, Jill Kinahan, Patrik Klintenberg, Alejandro León, Scott Morrison, Conrad Roedern, Elena Abraham, Richard S. Felger, Pietro Laureano, David Mouat, Boris A. Portnov, Uriel Safriel, Sabine Schmidt, Maurizio Sciortino, Andrew Warren, Daniel Zohary



Woman of the Bella tribe, Burkina Faso
Source: Jorgen Schytte/Still Pictures

People in Deserts: An Overview

People have lived in and around deserts since time immemorial where their activities and use of natural resources have been, and are, governed by the basic parameters defining all deserts. Rainfall, essential for growth and reproduction of plants and animals, for grazing and for agriculture, is a central factor. High temperatures and strong winds also influence people's use of deserts. Adaptations of people to these elements are different, mainly in degree but not in kind, from those of other animals and of plants. People have relatively few morphological and physiological adaptations with a predominance of behavioural, cultural and technological adaptations. People have used a variety of approaches to live in deserts and continue unusual innovations.

Although limited, the same physiological principles governing, for example, heat exchange in animals and plants pertain to human thermoregulation (Louw and Seely 1982). Humans, unlike many large mammals, do not pant in response to heat. Instead, humans sweat profusely and no other animal sweats as efficiently to support evaporative cooling. People can produce up to 4.2 litres of sweat per hour if well acclimated. Surprisingly, many people under hot conditions undergo considerable dehydration before drinking to replace lost body fluids. Heat stress, from increased body temperatures exacerbated by dehydration, may range from temporary loss of consciousness to stoppage of sweating, circulatory failure and death. Overall, key factors supporting humans in deserts are an adequate supply of water and shelter from the sun's direct rays.

Meagre physiological adaptations of people to deserts are more than adequately augmented by behavioural, cultural and technological adaptations. People are able to thrive in deserts simply by modifying their micro-environment. These modifications range from using natural shelters, for example caves or shade trees, to using appropriate clothing, to construction of dwellings and use of air conditioning. Behavioural, cultural and technological adaptations have evolved to ensure adequate food, water and shelter. The result of these adaptations has led to three major inter-related livelihoods: hunting and gathering, domestic livestock herding, and irrigated agriculture. While all these lifestyles are being practiced today, most have been extensively altered by modern technology.

Before describing traditional ways of resource use and management, brief consideration will be given to general aspects of people living in deserts. Protection from extreme heat and extreme cold is an important design consideration for desert clothing. Bedouin robes of light wool are considered to be an excellent compromise (Louw and Seely 1982). Evaporative water loss can be reduced by about one-third and heat gain by 55 per cent by wearing appropriate, loose-fitting clothing. Although white clothing will reflect solar radiation in the visible range, black or white clothes ensure the same body surface temperature. Nevertheless, two peoples living in deserts are known for wearing little clothing, the San people of southern Africa and the Aborigines of Australia (Biesele 1994, Bindon 1994).

Diet presents another aspect for consideration in hot deserts although basic requirements for high-quality protein, vitamins, minerals and sufficient energy naturally apply (Louw and Seely 1982). Adequate water intake is of primary importance and, contrary to popular opinion, the normal amount of salt used for flavouring meals is sufficient. Very high protein intakes are undesirable. If present in sufficient quantities, the traditional diet of West Asia, based on low-protein cereal grains and protein-rich leguminous seeds and featuring tea and coffee while excluding alcohol, fulfils most theoretical criteria for an appropriate diet in deserts.

Heat and aridity also are important in terms of housing. The physical principles governing the design of permanent desert dwellings are well-known. Thick walls and small windows protect from the day's heat but do not allow for cool air circulation in the often still night hours. In many areas, this leads to people sleeping outdoors or on the roof. Strong winds are also a consideration. These winds go by many names in different parts of the globe: the *Santa Ana* in California, the *föhn* in the Swiss Alps and the *zonda* in Argentina. People, other animals and plants must deal with the increased evaporation and very

low humidity of these winds. Moreover, solid edifices are not available to many desert dwellers, and other adaptations, for example low tents or transportable Mongolian *ger*, suffice while addressing the frequent occurrence of strong winds in addition to heat and aridity (for example, Flegg 1993).

This chapter will examine past and present livelihoods of people living in deserts, and their ever-changing relationships to available natural resources in these lands of scarce and unreliable rainfall, abundant sunshine, high temperatures and strong winds.

Traditional Desert Dwellers: Resource Use and Management

HUNTER-GATHERERS

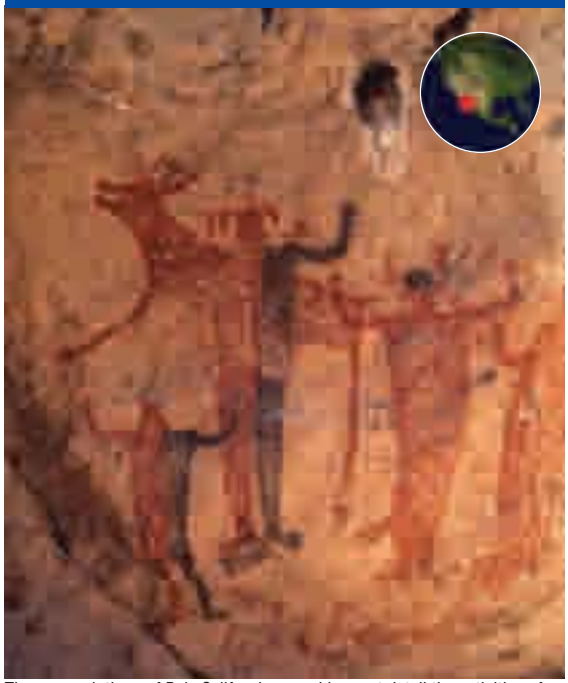
Early inhabitants of deserts, and all other environments, used resources in a way that is now described as hunting and gathering. In deserts it would have meant having the essential knowledge and being well-attuned to variable rainfall and the resultant growth patterns and behaviour of plants and animals, as well as to replenishment of ephemeral water sources. Certainly as far back as when *Homo erectus* occupied dry areas, it is thought that they used deserts on an intermittent basis when productivity was high (Shackley 1980). Interpretation of evidence from the central Namib Desert suggests that resource use was not simply a system of seasonal mobility, implying an almost random form of density-independent use of ephemeral resources (Kinahan 2005). Instead, an equilibrial or density-dependent system making use of key resource locations with reliable water during the dry season, within a wider area of ephemeral resources, would provide a better explanation.

A key resource essential for most groups of hunter-gatherers living in deserts is the presence of at least one tree-borne fruit that serves as a staple and is capable of long storage (Pailes 1999). This would be combined with grains, beans, roots and fruits, supplemented by small amounts of animal protein. In North America, acorns, pinyon pine nuts and mesquite beans fulfil this tree-fruit niche. In southern Africa, the mongongo nut and !nara seeds provide an equivalent. These resources could be harvested and consumed on site, but served an increasingly crucial role as baskets or pottery for transport and storage became available. They would have provided sustenance for traders and even served as trade goods as such relationships developed.

On the coastal deserts, particularly important on the west coast of the southern deserts (for example, Smith and Hesse 2005), use of marine resources would have constituted a large part of the diet, at least seasonally (for example, Kinahan 2000; and see Box 2.1). Prolonged occupation of coastal areas entirely surrounded by dunes but with fresh water seepage indicates the importance of marine resources for early hunter-gatherers (Shackley 1983). This rich diet may have relieved the necessity for a tree-borne fruit as a staple although in areas such as the Namibian coast, the !nara fruit, growing in the coastal dunes and ephemeral water courses, would have provided the necessary component (Henschel and others 2004).

Although hunter-gatherers occupied deserts for millennia, evidence for their livelihoods comes from archaeological (Figure 2.1) and recent observations

Figure 2.1: Cave paintings, Baja California



The cave paintings of Baja California record in great detail the activities of early desert hunter-gatherers. Such paintings, with small local differences, can be found in many places in African and Asian deserts as well.

Source: Patricio Robles-Gil

Box 2.1: Sonoran desert cornucopia — plants and animals in Native American culture

Those who do not know the Sonoran Desert may find it inhospitable, but the people who lived here had vast knowledge of the land and its plants and animals, and their ways of life were rich and diverse. Plant and animal resources across the desert are as varied as the region itself (Hodgson 2001; Felger 2006; Nabhan 1985; Rea 1997). Depending on where one draws the limits of the desert, its vascular plant flora consists of about 2 500 species in an area of about 300 000 km^2. People had knowledge and names for most of the plants and visible animals that are today known as species. In fact, like most people with close ties to the land, their folk classification often approximates modern concepts of genera and species. About 20 per cent of the plant species probably were used for medicinal purposes and about 18 per cent for food — although major staples were derived from a much smaller number (Felger and Nabhan 1978). Hence, across the entire Sonoran Desert (as defined by Shreve 1951), about 375 species of plants have been used for food.

People who lived along the thousands of kilometers of coastal desert in northwestern Mexico had easy access to a wealth of seafood the world may never again know. The Comcáac (Seris) of Sonora and the culturally extinct people of Baja California made use of a cornucopia of sea turtles, fishes, and molluscs, as well as the usual terrestrial animals and plants. The Seris also harvested eelgrass (*Zostera marina*) as one of their staples—the only known case of people using a grain from the sea as a major food (Felger and Moser 1985). Other peoples visited the shores of the Gulf of California for salt gathering as well as for seafood. Edible molluscs were often carried inland; especially Venus clams (*Chione* spp.), which could be kept alive and fresh for several days (Marlett 2005). Such shells litter ancient trails and campsites, and sustained an extensive trade in ornamental shells from the Gulf of California across the whole region and beyond (Felger 2006; Haury 1975).

The Sonoran Desert is home to peoples from several extremely different language groups. Within the major groups, such as the Uto-Aztecan Piman-speakers and the Hokan/Yuman-speakers and the linguistically-isolated Seris, there were dialects and myriad geographic and cultural differences. Despite this diversity, people of the Sonoran Desert did not live in isolation. Information and goods flowed among neighboring and even distant peoples (Ford 1983). People traveled and traded, talked to each other, and sometimes intermarried; they fought and took captives and adopted them into their societies.

Desert peoples such as the Seris, the Cochimí and others of Baja California, and the Hia C'ed O'odham (also called Sand People, Pinacate people or Sand "Papagos") of Arizona and Sonora lived in the driest regions of the desert, and obtained their food resources from what we call "hunting and gathering." Some Hia C'ed O'odham people, however, also had access to desert oases, where they practised agriculture and established more permanent residences. These desert peoples had very small populations, mainly because their water resources were extremely limited. Although outsiders considered them nomadic or semi-nomadic, they moved their residences within well-prescribed geographic limits according to schedules that varied with the vagaries of rainfall. They relocated to take advantage of different food resources but undoubtedly also for aesthetic reasons and, most critically, because of scarce water. Every water place was known in detail, and each had a name (Broyles and others 2006a). I once located a legendary waterhole in the Pinacate region of northwestern Sonora by following an narrow, ancient trail.

Seri people—just like many other people—like living or camping along the beach. They travelled to islands and hunted at sea using reed boats, or *balsas*, made of interwoven bundles of reedgrass (*Phragmites australis*) bound together with cordage fashioned from the fibre of mesquite roots (*Prosopis glandulosa*). They would carry their balsas to the top of high beach dunes to catch the sea breeze and have an easy lookout. When they changed to much heavier wooden boats in the twentieth century, they had to move their camps down to the shore.

People such as the River Pimas in southern Arizona and other O'odham groups (Piman-speakers), living farther inland along rivers or in regions of higher rainfall, had sufficient water for irrigation. Rich agricultural traditions existed along the several rivers that crossed the desert—the Colorado and its tributaries—as well as in many regions in the interior desert but on a greatly reduced scale. Some prehistoric Hohokam people in southern Arizona deserts built complex irrigation canals to transport river water to their fields. Their agriculture sustained substantially greater populations than the hunting and gathering livelihoods of non-agricultural people but ultimately fueled cultural collapse when the population exceeded the region's carrying capacity (Diamond 2005). The prehistoric Trincheras people of northern Sonora constructed extensive rock-walled terraces on desert mountains (McGuire and Schiffer 1982). Most of the terraces were on north-facing slopes and probably were used for the cultivation of century plants (*Agave* spp.). Elsewhere, such as desert bajadas northwest of Tucson, people grew agaves on artificial rock piles or "rock-mulch" constructs (Fish and others 1992). There is considerable evidence that prehistoric people made use of selected agave cultigens or domesticated land-race varieties (Hodgson 2001). Agaves were harvested throughout the region. When mature, the plants concentrate carbohydrates just before producing their life-ending inflorescences, and at this stage they are harvested and pit-roasted to produce large, sweet vegetable roasts (Gentry 1982).

People such as the Tohono O'odham in northern Sonora and southern Arizona diverted run-off water from sporadic summer monsoon rains onto their fields, which were widely scattered to increase the chance of getting water from localized and unpredictable scattered thunderstorm rains. The agricultural mainstays were the usual Native American trinity of maize (corn), beans, and squash. In the arid and semi-arid regions of southwestern North America, teparies (*Phaseolus acutifolius*) were the most common beans and were probably domesticated from local, indigenous wild teparies. The major edible squash was an indigenous cushaw squash (*Cucurbita argyrosperma* var. *callicarpa*). Although these crops were similar to the agricultural staples of the great Mesoamerican cultures, the desert people developed their own, highly diverse, desert-adapted varieties or land races. Their maize varieties were selected to mature especially fast because of the desert's short summer monsoon season (Fish 2004).

A trinity of legume trees was especially important to most of the Sonoran Desert peoples: mesquites (honey mesquite, or *Prosopis glandulosa*, and the closely related velvet mesquite, or *P. velutina*), palo verdes (mostly *Parkinsonia microphylla*), and ironwood (*Olneya tesota;* Bean and Saubel 1972, Felger 2006). All three produce large crops of edible pods or seeds in early summer. In the summer-rainfall parts of the desert, the giant cacti (for example, saguaro, or *Carnegiea gigantea*, and cardón, or *Pachycereus pringlei*) provided seeds rich in protein and oil. The large, succulent and sweet fruits of columnar cacti, especially saguaro and organ pipe (*Stenocereus thurberi*), were harvested not only for food but also for making wine. Coastal-dwelling Seris spent the full moon of May going up and down the coast drinking cactus wine and partying. It was a good time of year to enjoy a pleasant sea breeze while sitting in the shade of a ramada (an open shelter). In early summer as the saguaro fruit ripened, the desert O'odham held wine-harvest ceremonies to invoke the summer monsoon.

Seri woman harvesting wild wolfberries (*Lycium fremontii*) in the coast of the Sonoran Desert, by the Sea of Cortés

Source: Patricio Robles-Gil

Both plant and animal foods were prepared fresh and often also dried and stored for future use. A wide variety of vegetables, greens, fruits, and seeds were dried whole, sliced, ground, or made into cakes and stored, as were many kinds of animal foods such as sphinx moth caterpillars (*Hyles lineata*), shrimp, fishes, sea turtles, deer (*Odocoileus hemionus* and *O. virginianus*), and desert bighorn (*Ovis canadensis mexicana*). Many desert seeds are digestible only when the seed coat is broken, as when the seeds are ground on a grinding stone (*metate*). Most kinds of seeds and many other plant foods such as mesquite pods were parched, toasted, or dried and ground into flour, then boiled or steeped in water to be consumed as *atole* (Bean and Saubel 1972; Castetter and Bell 1942, 1951). No satisfactory term for *atole* seems to be available in English, the nearest approximations being "gruel", "mush", or "porridge". It is nearly impossible to avoid sand and gravel when preparing food on a grinding stone that rests on the ground or on a dirt floor. I once tried bread from eelgrass flour prepared on a metate; it tasted good, but the sand was not pleasant. If we had consumed the flour as *atole*, the sand would have been left at the bottom of the pot.

Dogs were the only domesticated animals but were not eaten (Rea 1981). Hawks and eagles were sometimes kept in captivity for their feathers. Some people kept and raised macaws, likewise for their feathers (Rea 1983). Old World-domesticated animals and plants were first brought to the region with the Coronado *entrada* to New Mexico in 1540, and in the same year to the lower Colorado and Gila River region by the associated Alarcón expedition (Flint and Flint 2005). Few if any of Alarcón's introductions survived, apparently, although some of Coronado's did. Padre Kino was the first and most important agricultural extension agent for the Sonoran Desert. He brought cattle, goats, horses, and sheep, as well as wheat and many other Old World plants in the late seventeenth century. Juan Mateo Manje, soldier and close associate of Kino, reported that in 1696 at the Dolores mission in Sonora there were "fruit trees of Castile, grapevines, peaches, pomegranates, fig trees, pear trees, and all kinds of garden produce," all brought by Kino (Burrus 1971:95). Other Spanish colonial introductions were cowpeas, muskmelons, pumpkins, various squashes, and watermelons. The major indigenous Sonoran Desert agricultural crops are all warm- or hot-season, frost-sensitive crops. Thus, wheat was especially appreciated because it is a frost-resistant winter crop.

Although Sonoran Desert peoples harvested hundreds of species of plants, a few dozen formed the primary resources. One unique major wild crop was the grain of *nipa*, a salt grass (*Distichlis palmeri*), harvested by the Cocopahs at the delta of the Colorado River (Castetter and Bell 1951). *Nipa* is a word derived from the Cocopah name for this grass, which is wholly endemic to the intertidal regions of the upper Gulf of California. It thrives on pure seawater as well as brackish water, producing large yields of a grain about the size of wheat. It is a strong candidate for a major global food crop and could become this desert's greatest gift to the world (Felger 2006).

Native Americans used a cornucopia of Sonoran Desert food resource species, but do not forget that this is desert country. Extended drought could mean hardship (Clotts 1917; McGuire and Schiffer 1982). No matter how rich the resources, drinking water was an absolute necessity. Camps and settlements or villages and towns had to have access to waterholes and oases or one of the rivers. The desert people moved seasonal residences for a number of reasons, such as to follow their favorite harvests, but especially when their meagre water supplies were threatened, when a place became polluted with waste, or perhaps just to take advantage of more pleasant conditions. Drought in the distant upper reaches of the Colorado River could spell trouble for the Cocopahs and other downstream desert peoples (Castetter and Bell 1951). There certainly must have been drastic changes for the lower Colorado River people when the river changed course to empty into the former Lake Cahuilla (the remnant lake is the Salton Sea) and the delta went dry or the flow was greatly reduced (Cleland and others 2000).

A desert is defined not only by low rainfall but also by unpredictability (Ezcurra and Rodrígues 1986). Even coastal, maritime desert peoples such as the Seris of Sonora and Cochimís of the Baja California peninsula would be affected by the vagaries of weather and sea conditions. The occasional sustained winds or red tide meant curtailment of resources from the sea. Extended drought or late frosts in inland desert regions could damage essential wild crops such as palo verde or mesquite pods. Desert peoples had to know how to live on flexible schedules but still sometimes suffered from shortages (Broyles and others 2006b). Summer rains were eagerly awaited. For Sonoran Desert peoples, the new year began when the fruits and seeds of desert legume trees and giant cacti ripened, heralding the brief monsoon, for this is the time of greatest renewal of life in this part of the world.

Box author: Richard S. Felger

Figure 2.2: Topnaar wild harvest

Two Topnaar people collecting !nara melons (*Acanthosicyos horridus*) along the dry water course of the Kuiseb River in the Namib Desert. The pulp of these melons is preserved by the local people by boiling it in drums and spreading it out to dry.

Source: Mary Seely

from their remaining cultural descendents. The Topnaar of the Namib Desert today know uses for 81 plant species, although it is thought that some knowledge has been lost (van den Eynden and others 1992; Figure 2.2). The San, or bushmen, of the Kalahari have a repertoire of over 100 species of food plants and 55 animal species, a list also probably more extensive in the past (Biesele 1994).

Hunting and gathering may have been the only way of life known to people when they first occupied deserts, even intermittently. With the slow evolution of use of domestic crops and animals, the livelihoods of hunter-gatherers took on aspects of herding and agriculture in varying proportions. The remainder of this chapter refers to "mixed livelihoods" of people in deserts, although one way of making a living may predominate for a period of time, or in a particular area, or for certain parts of the population.

In the rapidly developing world of the 21st century, hunter-gatherers necessarily undertake mixed strategies of resource use while trying not to lose their rich resource base. The San (Barswara) of the Central Kalahari are currently being relocated by the Botswana government out of what are perceived to be potential diamond mining areas. The San are an important element of most tourism experiences in southern Africa, and they have options for future development — although probably none represent their own preferred directions. In Namibia, a majority of the San are farm workers, mainly working for cattle-rich Herero peoples in the Kalahari sandveld (Gordon 2000), although they are also the nucleus of a very successful Community Conservancy focused on natural resource management and tourism (NACSO 2004). The future of the original hunter-gatherers of Australia, still very much focused on their traditional art and culture while adapting to modern ways, presents a similarly rich and complex transition (Bindon 1994, Kimber 2005). All modern day hunter-gatherers represent a repository of knowledge concerning life in desert landscapes, ready for interpretation and use that should not be ignored.

PASTORALISTS

Pastoralism refers to a livelihood approach that makes use of domesticated animals — for example, sheep, goats, cattle, camels — to provide a variety of products such as milk, skins, cash and occasionally, meat (Figure 2.3). Pastoralism evolved predominantly in Asian and African arid lands where most livestock were domesticated. Domestication is thought to have been undertaken by sedentary farmers rather than

Figure 2.3: Desert pastoralism

Desert pastoralism: Women milking goats, Irano-Anatolian Desert.

Source: Patricio Robles-Gil

hunters, as they would have had the capacity to corral animals for extended periods (Channell 1999a). Camels, the only livestock domesticated in hyper-arid deserts, are physiologically able to withstand desert conditions as they tolerate elevated body temperatures, are able to minimise water loss and reduce heat gain from the environment (Halpern 1999; Figure 2.4). They are able to tolerate water loss of more than 25 per cent of their body weight and can replace this within three minutes. They are without question well-suited to the desert environment and were responsible for most trans-desert trade before the advent of motor vehicles. Llama and alpaca are close relatives of Old World camels, and were domesticated to serve some of the same uses in the arid highlands of the Andes. Nevertheless, all mammals require water at frequent intervals, and in deserts this means herders must take livestock to temporary or permanent water holes, perennial or ephemeral streams and, in many instances, spend long hours lifting limited groundwater to the surface, often from great depths.

Other domestic animals are less well-adapted to deserts physiologically, but are nevertheless important for desert pastoralists. Sheep and goats represent the smaller, more tradable and expendable animals in southern African deserts, while cattle have greater associated prestige. Cattle (zebu in their humps), camels (in their humps) and sheep (in their tails) have concentrated fat deposits that store energy to carry them through times of limited pasture, but which do not hinder temperature regulation.

Based on different combinations of domestic animals, all forms of pastoralism incorporate an element of hunting and gathering, and many incorporate crop production as well. Most well-known are the nomads, with no permanent home base (Box 2.2). Entire families or groups move together with the herds. This is not a random movement, but usually follows fixed routes with careful scheduling based on rainfall and the presence of other herders (Flegg 1993, Pailes 1999, Smith 1994). Transhumance is the term given to livelihoods that include permanent villages and horticulture, augmented by seasonal movements of part of the group, often the men, with livestock to good grazing areas. This may

Figure 2.4: Desert travellers in Egypt

Desert travellers in Egypt approaching the pyramids on two traditional means of desert transport, a dromedary camel and a donkey.

Source: Patricio Robles-Gil

develop into a well-structured system where nearby grazing is protected and distant grazing used as conditions allow (Jacobsohn 1994, Pailes 1999). An important component of pastoralism is the presence of mobile merchants who, assuming many similar livelihood traits, support movement of products like salt, spices, grains, and necessities of life (Flegg 1993). The increasing complexity of interactions as pastoralism developed meant that individual families or small groups of hunter-gatherers changed to include more defined levels of organisation as an important component of living in and using ephemeral pastures and other resources of the desert landscape.

Mobility is a key to successful pastoralism in deserts as much as it is important for hunter-gatherers. Early herders followed rainfall and the variable grasslands that would appear in some areas in some years (Henschel and others 2005, Kinahan 1991). In some instances early herders harvested and ground natural grass grains as part of their resource base (Sandelowsky 1974). Nevertheless, there were distinct differences between strategies used to support differing livelihoods, as evidenced in the Namib Desert. While hunter-gatherers used reliable waterholes as periodic dry season gathering points, pastoralists with their herds spent dry periods in small dispersed camps. After good rains, pastoralists and their herds would aggregate wherever patchy rain provided good grazing (Kinahan 2005).

Box 2.2: Desert nomads

It is a surprise, in northern Niger, Chad or Sudan, to come across still-functioning nomadic economies. Is it such a good choice to live in a tiny tent hundreds of kilometres from the nearest shop? In fact, nomads could do far worse. Camels, sheep and goats fetch good prices, as settled people recognise when they invest large sums in livestock, and entrust them to nomads.

There have been for millennia, and they still are, purely sheep, goat, and cattle nomads in semi-arid areas, always many more than in the desert. The camel was the key that opened up the desert to the few. The Arabian camel (the dromedary) was adapted for nomadism in the 10th or 9th centuries BCE, at about the time of the domestication of the Bactrian (two-humped) camel in Central Asia. Both allowed much faster and further travel. Use of the camel spread throughout the dry parts of southwestern and Central Asia, northern Africa and the Horn of Africa. Extreme nomadism became both possible and necessary (in order to find sporadic grazing). Mobility had many other advantages: escape from oppressive laws and taxes, and contrarily, when these laws broke down, the ability to collect tribute from sedentary communities themselves.

Pastoral nomads cannot rely only on their herds; survival requires other things. To get these, nomads must trade their own products, sell their own labour (as for harvesting dates), or fish (for the market), if they live near the coast. Until 40 years ago they also transported travellers, pilgrims and goods (salt, drugs, slaves) on their camels. A few still do. Managing trucks, as they now must, needs similar skills in navigation and survival, and has taught new skills. Camels are still profitable for nomads in very arid areas, but sheep and goats, with higher rates of growth and reproduction and a better market, have replaced them in the less dry parts of the deserts.

When mobility was restricted by political boundaries, or the appropriation of land, or by severe drought, a small minority of nomads settled voluntarily. Some took up agriculture, but many transferred their innate adaptability to other theatres: finance, smuggling, or the military (Lancaster 1981, Chatty 1996).

How should planners now approach the nomadic realm? They have begun to act upon three realisations. The first is that nomads have minds of their own. The second is the large market for meat that nomads can produce from otherwise unproductive land. The third is the value of traditional, communal systems like *hema*; this Syrian approach has attracted praise in some quarters. After years of experimentation with Bedouin development, the government forbade cultivation in large grazing reserves, and developed a rangeland management programme for them. The results will need to be evaluated (Ngaido and others 2001). Another innovative approach is being tried with the Harasis nomads in Oman, who were asked what they felt about their future. Most wanted to keep livestock, for this was their main identity; some wanted to settle, but keep the nomadic option open; the new thing they most wanted was education (Chatty 1996).

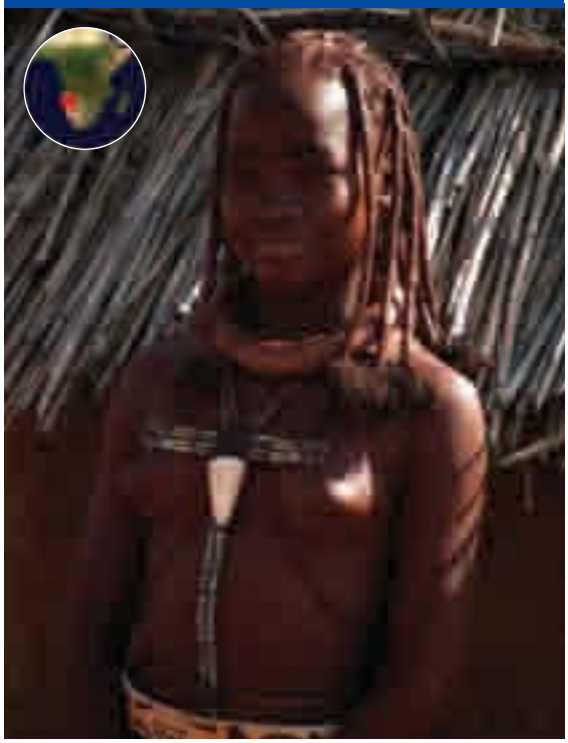
Box author: Andrew Warren

The Himba, the "ochre people of the dry riverbeds", are well known and admired for their herding prowess, particularly by those living in higher rainfall areas (Jacobsohn 1994; Figure 2.5). With the advent of rain, they move westward to annual pastures of the desert margins, preserving more permanent desert springs and their surrounding vegetation for the late dry season. For such a system to work, social relations and organisation are very important to the entire group. This is encapsulated in their saying: "don't start your farming with livestock, start it with people". A system where inheritance through females relates to material wealth, while residential units and authority are inherited through males, serves to strengthen the needed social organisation. Contrary to many declining pastoral groups in arid southern Africa today, older people make sure that younger herders have full access to all available knowledge for successful use of the desert landscape.

For many centuries, pastoralism has been an important livelihood in the deserts of Asia, such as the Gobi (Box 2.3). Pastoralists manage the greatest proportion of desert lands, for subsistence or for profit, but alternatives ranging from hunting to tourism on desert pastures are emerging. On the other hand, increasing population, changing politics, enhanced educational opportunities and globalisation are all influencing pastoralists of the desert realm.

Today, pastoralists do not necessarily live in deserts but continue to herd their animals there to provide valuable products for urban consumption. Camels are being replaced by cattle with their better market value, and four-wheel drive vehicles provide transport (Smith 1994). It is a way of life that is rapidly changing, but nomads are still considered to be the most efficient producers of meat in deserts. Because of the large areas they use, they

Figure 2.5: Himba woman, Kaokoveld, Namibia



This young woman displays traditional jewellery with a white conch *ohumba* from the west coast as centrepiece. Her hair style indicates that she has recently completed the puberty ceremony and is now ready for marriage.
Source: Patricia Rojo

are profoundly affected by changes in politics and the environment, and their future is variable and unpredictable (Marx 1994).

IRRIGATED AGRICULTURE

Agriculture has been important to people in deserts since domestication of crops began. Rain-fed agriculture is less important in deserts than in higher rainfall areas because of the scarcity and unpredictability of rain; alternative systems began as attempts to reduce risks imposed by rainfall variation. Irrigated agriculture has evolved in different ways in different places based on different situations and crops available (Figure 2.6).

Large perennial rivers running through deserts, for example, the Nile, Tigris-Euphrates, Rio Grande and Colorado rivers, have supported desert people and their irrigation for a long time. Of particular importance on the Nile was the annual flooding and deposit of nutrient-rich silts on alluvial soils as well as prevention of salt accumulations (Dregne 1999a). All these benefits stopped once the Awsan High Dam was built in 1970 and alternative fertilisers and salt removal techniques are being tested. The Nile Delta is shrinking for lack of silt deposits and the final solution has not been identified. The Colorado River supports some agriculture but is better known for supplying water and electricity to major urban centres in Arizona and California (Channell 1999b). Its delta has lost most of its water and hence its productivity. The Tigris and Euphrates basin has been occupied by people for millennia and is part of the Fertile Crescent with its early irrigation and urban developments (Dregne 1999b). The lower marsh has been recently drained and its contribution to agriculture eliminated. Silt in the river water and salinization of the irrigated land have been ongoing problems. Clogging by silt can be addressed by individual farmers for smaller canals, but peace and political stability are required for maintenance of large river systems of 300 km or longer.

Small-scale rainfall harvesting in deserts has been adapted to specific types of terrain, climate conditions and choice of crop (Lövenstein 1994). None of these approaches lend themselves to large scale, mechanised farming, but have provided abundant agricultural products for desert people. The terrace system was probably one of the

Figure 2.6: Modern desert irrigation

Menonite irrigation farmer in the Chihuahuan Desert. Melons are commonly grown throughout the deserts of the world.
Source: Patricio Robles-Gil

Box 2.3: People, pastures and protected areas in Mongolia's Gobi desert

Mongolia's Gobi Desert is an old cultural landscape, managed by nomadic livestock herders and sedentary cultures for millennia. Throughout the area, petroglyphs etched into dark rock faces illustrate human activity, their interaction with the environment, and the human view of wild and domestic animals over different periods of the last 2 000 years.

The Gobi Desert is a grand and diverse landscape from where vast expanses of steppe mountain ranges rise to rugged peaks, their slopes green with patches of juniper and forest remnants on more sheltered sites. Giant sand dunes contrast with deep gorges filled with ice even at the height of the desert summer. During the long winter and even more so in early spring, this desert steppe is exposed to high winds, and herders and their livestock seek shelter in their winter camps, often in lower mountain reaches or higher in quiet valleys, while alternating snow and sandstorms can continue for weeks. The Gobi is the coldest desert on earth, where the seasonal temperature difference within a year may reach 80°C.

A nomadic herder riding across Mongolia's Gobi Desert.

Source: Sabine Schmidt

Pastoral land-use practice has evolved over millennia to make optimal use of spatially and seasonally highly variable pasturelands in drylands that receive less than 200 mm of precipitation annually. Desert vegetation in turn has adapted to grazing by domestic livestock and by wild ungulates. Desert species important as livestock fodder plants have evolved buds close to the ground, allowing regeneration after grazing, and large areas of the Gobi every year are covered in a green carpet of a species of leek resistant to permanent grazing impacts. As long as mobility of livestock herds is maintained, desert steppe pastures are resilient.

Nomadic livestock herders in the Gobi used to undertake long distance migrations, moving seasonally north into the forest steppe zone. Centralized government and planning of administrative and economic units during Mongolia's socialist time, under Soviet dominance, brought an end to most long migrations. Pasture use coordination was directed within the state collectives and mobility was facilitated with state support. With the demise of the Soviet Union and collapse of the centrally-planned economy and government, a vacuum of institutions for grasslands management was left in rural Mongolia. For lack of other income opportunities, many households turned to subsistence herding, keeping private livestock on state-owned land. Many of those lacked traditional herding skills and had only small herds with not enough transport animals to move their camps. A cycle of poverty and land degradation set in, making already weakened livestock very vulnerable to cyclical winter disasters occurring in the region. A dramatic loss of 7 million livestock countrywide and a tragic rise in rural poverty occurred between 1999 and 2003.

The truth that institutions lie at the heart of livelihoods was felt by herders of the Gobi. Their pastures were degrading through a lack of coordination among them and through a lack of mobility. Throughout the area, pasturelands were becoming unusable for lack of water supply as wells were not maintained.

Triggered by the need to restore mobility, and supported by technical assistance, herder communities in the Gobi began to organize. Collective action, now voluntary, revived customary institutions for local natural resource management. Community norms for pasture use improved grazing resources and livestock. By working together, herding households could improve their preparedness for winter and natural disasters, add value to products and market them, access services and link with resource agencies. Livelihoods began to improve and pastoral community organization generated important lessons for poverty reduction in the country. A new adaptation was underway — customary institutions adapting to the new socio-economic and political landscape. The herder community organizations that emerged as institutions for natural resource management and conservation have become important actors in rural development and a driving force in a fledgling civil society.

New livelihood strategies are now being developed. Drawing on their rich cultural heritage, Gobi livestock herders now run their own Herders' Tourism Network, providing visitors with travel by horse and camel, and introducing them to the local culture and environment.

Box author: Sabine Schmidt

earliest irrigation systems involving a series of stone walls across a water course. With rain, the terraced fields would fill up and excess water cascaded onto fields below. Perhaps as a next step, the hillside conduit channel system was established based on narrow channels from neighbouring hill slopes. Micro-catchments, still in use today, have for thousands of years enhanced water application

Box 2.4: Oasis agriculture

"Oasis" has become a metaphor for refuge, and many oases in the desert are just this: welcome shade and security in a blisteringly hot and dangerous environment. The metaphor has had long enough to develop, because oases have a long history, and with care, they will have a long future. Some oases are visited only occasionally, for planting new trees, or for harvesting a few dates; some support a few hundred families in permanent homes; the oases around the old city of Bukhara, in Uzbekistan, support 1.2 million people, on 230 000 ha of irrigated land; those along the Tarim River in western China or the Nile in Egypt, support many millions of people. Huge cities, like Cairo, Damascus, Baghdad and Urumqi, depend largely on the production of oases.

Shaduf used by Topnaar people in the Kuiseb River, Namib Desert, to obtain domestic water and water for their livestock before solar pumps were introduced in the 1980s. The alluvial aquifer depth ranges to about 8m below the surface.
Source: Mary Seely

Some of the ancient hydraulic systems that harvest water onto oases still astonish. The *qanat, foggara, karez* or *falaj* system leads water, from deep in an alluvial fan in a mountain basin, down a gently sloping tunnel to an oasis. The water is found with a well, sometimes hundreds of meters deep, and the tunnel from it is marked on the surface by a line of maybe hundreds of other wells for ventilating the well diggers and getting rid of their spoil. Other oases are fed by springs or mountain streams which are led into channels; some hacked out of the sides of gorges, others taken over small aqueducts. In northern Chile, pre-Columbian channels watered flights of irrigated terraces, covering hundreds if not thousands of hectares, now mostly abandoned. Yet other oases depend on water diverted from large rivers, at temporary or semi-permanent weirs, into intricate canal systems, as along the great rivers of early Mesopotamia, the Indian subcontinent (from the Harappan to the Moghul periods), Kazakhstan and western China. The Great Dam of Ma'rib in Yemen functioned for over a thousand years, and once watered 9 600 ha. It succeeded partly because it diverted rather than stored water, and therefore was not silted up, like many modern dams (Brunner 2000). Deep in the desert, far from rivers, as in much of the Sahara, oases depend on wells. If the wells are shallow, the water can be lifted to the surface by cantilevered bucket systems, or *shadufs*, by Archimedes screws, or by water wheels powered by oxen. All these systems (even at Ma'rib) are vulnerable. *Qanats* may collapse, and if specialist *qanat* engineers are not on hand, the dependent oases wither away. Rivers can change their courses, and isolate the off-take canals, or flood and sweep away the weirs that guide water into them. For these, and other reasons, many oasis systems have themselves collapsed. A newer threat, coming after the introduction of mechanical pumps and deep-drilled wells, is the heavy use of ground water, to the extent that the water-table retreats, as it has now done in many Saharan oases (Ebraheem and others 2004).

When water reaches a Muslim oasis, it is taken first past the mosque (where it is used for ablutions), and then to the gardens. In some Omani (and many other) oases, a committee controls the distribution of the water, so that no plot is dry for too long. A notice, pinned near the mosque, announces the next meeting of the committee. Most of these arrangements are cumbersome, and can be stultifying, so that many entrepreneurs today evade them by digging a well mechanically and installing a mechanical pump to feed a plot outside the old oasis. Communal systems that are less easily evaded are also needed to protect the encroachment of sand, as in Al Hasa in Saudi Arabia, in the Nefzaoua of southern Tunisia, or in the neighbouring El Souf region of Algeria.

Water brings nutrients to the fields, which are almost as important to sustainability as the water itself. In the San Pedro de Atacama oasis in northern Chile, where the river is particularly rich in silt, 37 500 million tons of material (a thickness of 180 cm) was deposited on irrigated fields between the mid-16th and the mid-20th century (Bork and others 2002). The water also brings salts, which accumulate in the soil as the water evaporates, and are a constant and common threat to sustainability. Moreover, studies of ancient systems, like that fed from the Ma'rib dam, or parts of Oman, show that some traditional systems used enough water to wash salts through the soil (Luedeling and others 2005), or irrigated very well-drained soils, as at Kharga in Egypt (Brookes 1989). If salts did build up, crops that were less susceptible to salinity, like the date palm, would gradually displace more vulnerable crops. But as the scale of water application increases, and unless drainage is managed, salinity can become a major threat to sustainability, as it is now in the oases of western China, and in Siwa in western Egypt, and as it once did in ancient Iraq. In oases that depend on well irrigation, salt is concentrated in the irrigated soil by evaporation, and may then seep back to the well water (Wang and others 2000).

Oases produce many types of crop, the most common being dates, other tree-crops like mangoes, vegetables, cereals like wheat and the more salt-tolerant barley, and fodder crops like alfalfa (and protein-rich quinoa in the Andes). Many local varieties of all these crops have been developed to suit local conditions (Moore and others 1994). Connoisseurs know the best oases for things like mangoes. Dates are now a major source of income in the north African (and some North American) oases. Other cash-crops, like early vegetables grown in plastic tunnels (as in Tunisia), or grapes for wine production (as in Argentina) are now profitable. The crops were once protected from pests by indigenous systems (Parrish 1995), but pesticides are now widely used (and overused). Harvesting was often achieved with temporary employment, as of nomads. Oases have a long future, but only if traditional wisdom about local conditions can be welded to new technology, and if new systems of environmental monitoring can be used to warn of threats to sustainability.

Box author: Andrew Warren

to small scale catchment areas. On a larger scale, diversions have been used on small and large, perennial and ephemeral rivers to channel water onto terraced fields on adjacent plains or even at a distance. Oasis agriculture has developed wherever water is available and has taken on many forms. A unique water harvesting system for oases is the *foggara*, which augment the water supply of isolated oases and small villages in places where it was not sufficient to encourage extensive settlement (Box 2.4 and Box 2.5).

With much ingenuity and hard work, different people in different areas supplied by an assortment of water sources have developed systems for crop production. Original savanna crops such as millet and sorghum have been adopted for desert use. Palms, tamarisk, acacia, and *Zizyphus* as well as tubers, fruits and cereals were all part of the Sahara array of crops when rains were more plentiful several millennia ago (Reader 1997). Palms, however, are the only species known to have been domesticated directly in deserts (Box 2.6).

Hunting and gathering, pastoralism and irrigated agriculture all advanced, at different rates and different times, with different innovations. Baskets and pottery for transporting food and other goods allowed people to gather and carry more food and other materials. Deserts have always been a part of the global environment with desert peoples trading within deserts and with neighbouring cultures (see Chapter 3).

Population constraints within deserts, imposed by changing climates and agricultural developments, have caused wide fluctuations in the numbers of desert inhabitants (Reader 1997). With the expansion of technologies supporting people to live in deserts, the degree of fluctuation may be reduced. Nevertheless, institutions focused on resource management, as required for successful

Box 2.5: Harvesting underground water

The technique of underground water harvesting dates back thousands of years and has been adopted over very large areas stretching from China to Spain, and as far as Latin America, to mitigate the effects of arid climates.

Underground canals, called *qanat* in Iran, *foggara* in North Africa and Cyprus, *aflaj* in Oman, *karez* in Pakistan, *magara* in Jordan, *khottara* in Morocco and *madjirat* in Andalusia, may extend from a few hundred metres to several kilometres in length.

It is difficult to establish if these various systems derived from knowledge dissemination or from independent innovations in areas with the same physical characteristics. The existence of many ancient towns was based on these systems. One variation of this method of water production and the associated complex management procedures is efficiently used in the regions of Gourara and Touat in the Algerian Sahara desert with about one thousand *foggaras*, half of which are still working.

Foggaras consist of underground tunnels dug parallel to the ground surface. They do not reach the groundwater but drain off soil water, preventing lowering of the aquifer. The subsoil area for water supply acts like a big rocky sponge rather than an underground basin. *Foggaras* can be easily identified by the wells on the surface, recognized by their characteristic raised edge resulting from the excavation wastes. The wells are dug about 8 to 10 metres apart in order to guarantee proper ventilation during the underground digging; they are also used for maintenance work but are not used for extracting water.

Excavation of foggaras starts from the settlement site and follows the edges of the alluvial cones of the fossil wadi. Unlike a feeder canal, the foggaras do not convey water from springs or underground pools to the place where it is used. Instead, they tap micro-flows seeping through the rocks.

Foggaras may be supplied by three different processes:

1) Underground water flowing under the sands of an *erg* coming from distant rainfall on the highlands, for example, on the Saharan Atlas. Precipitation happened thousands of kilometres away, and it takes the micro-flows thousands of years to cover this distance under the sands of the *erg*, and to reach the oasis where the prehistoric rainfall is harvested.
2) Atmospheric supply from rainfall, which in these regions does not exceed 5-10 mm per year. Though it is quite a small amount of water, because of the enormous basin size, it can provide an oasis with a significant contribution.
3) Condensation of atmospheric water vapour may also contribute.

In contrast to our understanding of the *qanats* in Iran, quantitative assessments of the contribution of the three processes to foggara productivity and of the way the air condensation drainage tunnels work have not been elaborated.

Box author: Pietro Laureano and Maurizio Sciortino

Box 2.6: Plant domestication in desert environments

The climatically extreme desert biome is not an ideal location for practicing agriculture or for domesticating plants. In fact, in hot and dry desert areas, the shift from hunting and gathering to farming and herding took place relatively late. It depended, almost exclusively, upon two factors: (a) human introduction of crops that originated in milder and more humid biomes, such as steppes, grasslands, chaparrals, savannahs and park forests, and (b) the development of various types of irrigation systems. The only indigenous wild desert plant definitely domesticated in its native harsh environments appears to be the date palm (Zohary and Hopf 2000). Also, prospects for future domestication of true desert plants are far from bright. Medicinal plants as well as large ornamental species (such as succulent Chenopodiaceae, cacti or Euphorbias) seem to have better chances.

Date palms are the only fruit tree that were strictly domesticated in the desert.

Source: Daniel Zohary

The date palm, *Phoenix dactylifera,* is the best-studied example of successful domestication under extreme desert conditions (Wrigley 1995). Both cultivated varieties and wild forms of this fruit tree are adapted to extremely hot and dry climatic regimes that prevail in the West African, Arabian and Saharan deserts. Today, date palm plantations are a characteristic feature of sparse oases. Wild-growing forms of this palm (from which the crop could have been derived) also thrive in these harsh territories. Archaeo-botanical finds indicate that they are indigenous, at least in West Asia, including Arabia.

The date palm is a very productive fruit crop and a basic, staple food of local people. Ripe fruits of cultivated date palm varieties are packed with sugars (about 70 per cent of dry weight) and fruit yield is about 30-40 kg per tree under primitive farming and two to three times these amounts in modern plantations. It is extensively planted in Saharo-Arabian countries as well as in southern California and Arizona. The present annual world production is over 5 million tons, mostly consumed locally.

For effective pollination, fruit setting and fruit maturation, the crop and its wild progenitor require mild winters, intensely hot and fully rainless summers, very low relative humidity and permanent water supply (which can be quite brackish). Arab folklore has cleverly summed up the ecology of the date palm: “Its feet are in the water and its head is in the fire of the sky”.

Closely associated with development of date palm horticulture was the Bronze Age domestication of the single humped dromedary camel, again probably in Arabia and/or other parts of West Asia. Similar to the date palm, the camel is a desert specialist perfectly adapted for survival in harsh, arid environments. Herding and rearing of camels added a supply of milk and meat to the date palm diet, as well as strong pack animals capable of traversing the hostile Saharo-Arabian deserts. This combination was largely responsible for opening these vast territories to human activity.

Box author: Daniel Zohary

hunting and gathering, nomadism, transhumance and oasis agriculture, will undoubtedly play a large, although altered, role in future desert development.

Modern Desert Dwellers: Resource Use and Management

People living in deserts today vary qualitatively and quantitatively in their development trajectories and their use and management of desert resources (Box 2.7). Some groups are more or less successfully continuing in their traditional ways, often against great odds, while adapting to developments taking place around them. An example would be the Harasis nomads in Oman: some are maintaining their livestock while others are settling down, but all want education to understand, if not completely partake of, “modern” developments. Others, such as the Topnaars of the ephemeral Kuiseb River in Namibia, consciously maintain their traditional roots in villages along the river where old people oversee the livestock and bring up children not old enough to attend school (Henschel and others 2004). Irrigation farmers along the Nile continue farming while adapting to controlled river flow and its reduced silt load and increased salt deposition. Camel nomads of the Sahara continue long-distance trade and transport, but have shifted emphasis from camels and trade goods to motor vehicles and tourists. Similarly, a majority of bushmen (San) in Namibia are farm workers while others are members of a conservancy focused on wildlife conservation and tourism. Nevertheless, the San supplement their income using natural products from the veld and maintain their art and cultural traditions for themselves and for tourists. Because deserts

Box 2.7: Mendoza, Argentina: Two faces of the desert

Mendoza, located in central-western Argentina on the eastern piedmont of the Andes, is a clear example of the opportunities offered, and the restrictions imposed, by deserts. A region of natural contrasts, it is also marked by deep social contrasts reflected in two Mendozas. One, rich and ostentatious in the irrigated oases, is built at the expense of the other: the non-irrigated desert, only inhabited by isolated producers of livestock, mostly goats (Abraham and Prieto 2000).

The 1 000 m elevation divides the territory into two halves, with mountains and piedmonts on the west, and lowlands on the east. The main perennial rivers, which feed from snow and glaciers in the Andes, form large alluvial fans on the plains, allowing development of irrigated "oases" that concentrate the productive, social and political life of the province. Waters of the Mendoza and Tunuyán rivers in the north, the Diamante and Atuel rivers in the centre, and the Malargüe river in the south, supply irrigation water for between 2.5 and 4 per cent of the province's area. Despite their limited extent (approximately 3 600 km^2), these oases support nearly 95 per cent of the population. Productive activity in the oases is structured as an agro-industrial model in a market economy, made possible by systematized irrigation and use of groundwater. Industrialization is mostly associated with produce from vine, fruit and vegetable crops (Roig and others 1991).

Water use is based on water law and on irrigation endowed with an active democratic participation of water users. Users vote for water supply managers who are responsible for distribution of water to each user and for water-use schedules, and who have their own funds. Advisors representing different rivers in the province and commissions at the provincial departments complete this administrative model.

Territorial imbalance appears in the development of irrigated oases to the detriment of areas lacking in irrigation water, and is crystallized in the contradictory phrases, *"culture of the oasis" – "culture of the desert"*. Competition for water use emerges as one of the primary environmental conflicts in the interaction between oasis and rain-fed areas. Rain-fed areas are characterized by low population, inefficient road systems, and dependence on equipment from distant urban centres. Extensive livestock and cattle-rearing predominate (Montaña and others 2005).

Economic globalization and its related integration processes impose new rules for development on the society and economy. The perspectives of provincial development are focused not only on consolidating access to international markets but also, and most importantly, on consolidating policies likely to result in higher territorial and social equity. When policies are formulated only for the oases, decisions are being made, by omission, about non-irrigated spaces, submitting them to a subordinate role. The myriad challenges include: developing systemic criteria for water use, (both surface and groundwater), rationalization of livestock rearing, production diversification, legalization of land tenure for the "occupiers" of the desert, territorial arrangements to guide urbanization processes, equity in the distribution of water resources, incorporation of appropriate technologies for water use and for the use of resources in general, as well as the recovery of traditional knowledge.

Box author: Elena María Abraham

harbour a number of diverse and seemingly exotic cultures living by a variety of lifestyles, they are inherently attractive to tourists from temperate climates. While some desert people continue their usual livelihoods and have "inadvertently" become tourist attractions, others are integrated directly into or are working for the tourism industry – with many levels in between.

Another culture whose presence has long been felt in deserts is that of mining. Wares of gold miners were carried across the Sahara to Europe by camel caravans for centuries. Salt mining produces another image associated with deserts and camels in northern Africa as part of a long-established, integrated trade network. The coasts of South America and southern Africa were densely populated for a few years while ships from Europe removed guano accumulated over millennia, or as in Namibia, established whaling stations for a few years (Kinahan 2000). Another type of mining has become almost synonymous with deserts over the past several centuries, that of extracting oil and, more recently, uranium. The riches generated by these different types of mining supplied the income necessary to import missing resources from food to water and infrastructure. Large urban areas in deserts are now entirely dependent on imported resources, for example energy from oil for desalination of all domestic water and all other energy required by the city of Kuwait.

Several entirely different groups are taking advantage of the desert's vast landscape and unique scenery, dry air and almost continuous sunshine to relocate from less comfortable climates. With no traditional ties to these areas, retirees with adequate funds, those seeking a health cure, those seeking nearby recreational opportunities, or those just wishing to live in less arduous environments, are flocking to what were only lightly populated desert areas just a century before. Resorts, golf complexes and shopping megalopolises are also booming in desert

Box 2.8: Cities and deserts

Most major population centres of the contemporary world are located outside deserts. At their beginning, many of these centres were established as small agricultural communities for which access to fresh water was essential (Portnov and Erell 1998). In contrast, urban development in deserts often generates sufficient economic outcomes to justify the considerable costs of importing fresh water (Portnov and Safriel 2004).

Historically, desert settlements have been scattered and sparse, and served as commercial and administrative centres, which sprang up around mines, transportation routes, and other local amenities (Saini 1980; Golany 1979; Issar 1999). Some were established as strategic outposts in response to various geo-political and security considerations (Portnov and Erell 1998). Today, desert towns and cities function as irrigation centres, garrisons, communications nodes and political, administrative and regional centres; they also may be focused on tourism, recreation, mining or other industries (Kates and others 1977).

Planned (bottom) and unplanned (top) development in a desert urban centre, Nouakchott, Mauritania.

Source: Stefanie M. Herrmann

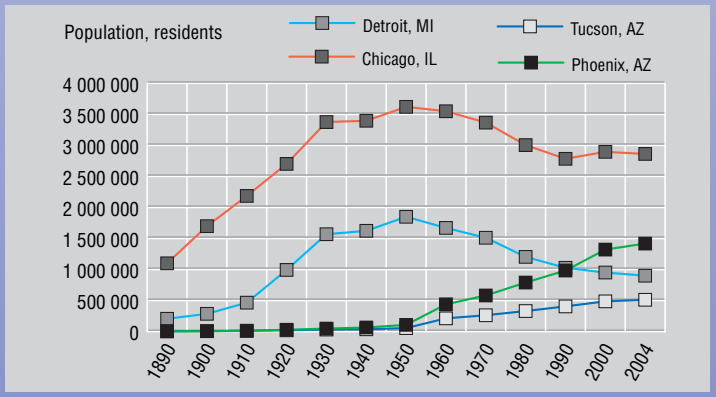
There are four major factors contributing to a recent increase in the pace of desert urbanization:

- Relocation of territory-consuming enterprises, military and research installations from overpopulated core regions to peripheral desert areas;
- Mining and power engineering facilities, as resources are depleted in traditional mining centres and other less remote non-desert locations;
- Development of transport infrastructure which extends the commuting frontier of existing population centres into more remote desert hinterlands;
- Development of means of pumping fresh water over considerable distances from natural sources, and desalination technologies which have become more available and affordable (Portnov and Erell 1998).

Desert cities of today (red dots) and cities located at desert fringes (blue dots), which are being at risk of becoming desert cities in the future due to anticipated climate change and resulting desert expansion. (A) Africa and West Asia; (B) South America; (C) Central and South Asia; and (D) North America.

Predicted global warming will also draw the desert frontier closer to many existing population centres, thus bringing more cities currently located at desert fringes closer to the desert; some may even become desert cities eventually. Thus, as a result of climate change, more non-desert people of today are likely to become desert inhabitants of tomorrow.

Concurrently, two major factors reduce the attractiveness of desert regions for newcomers — limited and undiversified employment opportunities and remoteness from major cities, which are major foci of employment, services and cultural life. However, if these drawbacks are mitigated, desert cities may exhibit impressive growth (such as in, for example, Tucson and Phoenix, Arizona), outranking even long-established non-desert communities. Environmental impacts of desert urbanization are not negligible. Compared to agriculture, however, urban development is compacts and economical on land use, thus leaving more spaces for environmentally-compatible desert uses, such as tourism and recreation (Portnov and Safriel 2004).



Comparative trends of population growth of selected cities of the United States

Source: U.S. Census Bureau

Box authors: Boris A. Portnov and Uriel Safriel

environments (Box 2.8 and Box 2.9). These new uses are developing simultaneously with other uses of the vast open spaces of the desert, such as military training grounds or, as in western China, resettlement areas to open up “new frontiers”, release population pressure elsewhere, and provide a buffer against neighbouring states. While deserts are opening up for urbanisation and associated use, areas including cites and towns bordering deserts may inreasingly find themselves within deserts as global climate change takes place.

Resource use and management in desert areas for “modern” development focuses on two key resources, one of which is very scarce and one of which is highly abundant. By definition, water in deserts is limiting . It is usually brought from great distances (like in southern California), often disadvantaging the people from where it comes (Reisner 1986). It may require construction of large dams cutting off people in the lower reaches, as in the Colorado River. Or it may result in drawdown of hard-rock or alluvial groundwater aquifers altering local availability as well as livelihoods of distant populations (de Villiers 2000). Desalination of water for domestic use is increasingly considered and extensively used where energy is abundant. Appropriate use of water in deserts will have to be

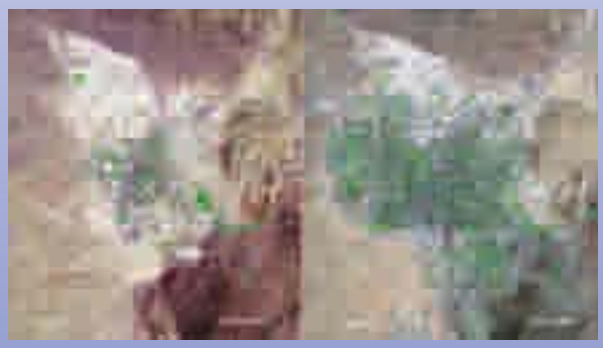
Box 2.9: Las Vegas

Las Vegas, home to the fastest growing area of the United States, is situated in a valley, or down-dropped fault block, within the Basin and Range Physiographic Province. The valley is filled by recent alluvial and lake bed deposits from the surrounding mountains. The name, “Las Vegas”, means “the meadows” in Spanish, a name that might confuse today’s visitors and even residents as there are few meadows to be seen amidst the sprawling and endless stretches of subdivisions, casinos, malls, and other developments. Ironically, for an area that was known in the 19th and early 20th centuries for its abundant water resources, the Las Vegas area is one of the great consumers of water in the American West.

One reason for this water consumption lies in its arid climate (an average of approximately 100 mm of rainfall per year, combined with temperatures that regularly top 45°C in the summer and can reach 48°C), but the main reason is its spectacular growth and the need to appear well-watered to tourists. Las Vegas has been the fastest growing large metropolitan area in the United States, growing from approximately 340 000 people in 1972 to over 1.7 million by 2002. The 1972 and 2002 Landsat images illustrate the growth. The implications are tremendous. Certainly it is an economic boom to the various industries that provide for the growth. Most of the 35 million tourists who visit the area also probably see it as favourable. But growth also has costs. The meadows (the photo of nearby Ash Meadows illustrates what the area probably looked like prior to urbanization) are virtually no longer present. Many unique plant and animal species have vanished. Recreational activities for both residents and tourists mean increased pressure on a fragile desert ecosystem. One of the most severe threats comes from proposals to import water from lightly populated east central Nevada, home to just a few thousand people who live above a tremendous aquifer. A transfer of that water to Las Vegas could well bring an end to numerous seeps and springs by drawing down (lowering) the aquifer.

Ash Meadows is located about 150 kilometers from Las Vegas near Death Valley National Park. According to Dr. Don Sada, an internationally-known arid system aquatic ecologist, Ash Meadows represents a system that supports 24 endemic fish, plants and aquatic invertebrates. All of these fish and plants are listed as threatened or endangered by the U.S. Fish and Wildlife Service. This is the highest concentration of locally distributed endemic species known in the U.S. and the second highest known on the continent. Las Vegas, at one time, probably looked somewhat similar.

Source: Don Sada



Landsat images of Southern Nevada including the metropolitan area of Las Vegas. In arid areas such as this, there is little natural vegetation cover, except for riparian zones. The Las Vegas Wash, located in the lower right center of each image, has dense vegetation and appears bright green. It can be seen emptying into an arm of Lake Mead. Las Vegas, itself, is largely green, indicating irrigated landscapes and golf courses.

Source: UNEP/GRID-Sioux Falls

Box author: David Mouat

re-evaluated in the decades to come, particularly as food production is an increasing competitive use for growing desert populations.

Energy is the second key resource essential for "modern" development and it is present in deserts, again almost by definition, in great abundance. To date, developers in deserts have largely ignored the abundant solar energy available and relied on increasingly expensive traditional sources of energy, like water, often brought from great distances, or otherwise on polluting the clear desert atmosphere – a main reason people come to the desert environment in the first place. Abundant solar energy could contribute to development not only of deserts but the entire globe (see Chapter 5).

ALTERNATIVE BENEFITS AND USES OF DESERTS

Deserts have not only supported and continue to support a variety of livelihoods; they have contributed extensively to global culture, traditional and modern (Figure 2.7). Three of the world's major religions had their origins in the deserts of West Asia (Mares 1999). Judaism, Christianity and Islam, the three "religions of the book", grew out of the profound religious experiences of desert cultures. All three religions are monotheistic, and today have enormous geopolitical influence extending far beyond their area of origin.

On a totally different level, today's culture and perspectives on deserts are greatly influenced by movies made in natural desert landscapes where the harsh habitat is usually portrayed as hostile to the presence of people (Ocampo 1999). A common theme of these films is isolation in a vast, arid landscape with its climatic extremes, scenic contrasts and limited supply of water. As a result, in the United States and to a lesser extent in Australia, the desert environment, combined with efforts to overcome its trials and tribulations, has become symbolic of national character.

Partly fuelled by landscapes and challenges depicted in movies, deserts have become favoured destinations for tourism and outdoor recreation. However, tourism, if it includes pilgrimage, is nothing new in deserts, and is a strong driver of change. Small-scale pilgrimage has a long history and is a common modern practice in deserts (Marx

Figure 2.7: Traditional cultures

A Seri woman performs an age-old ritual ceremony in the coast of Tiburón Island in the Sea of Cortés, Mexico

Source: Patricio Robles-Gil

1977), but by far the most important pilgrimage in the deserts today is the Hajj to Mecca and Medina. The Hajj now attracts some four million pilgrims, in just one month of each year. It is certain to achieve yet more change, not only in Saudi Arabia, where it already generates much income and fast urban growth, but also by bringing Muslims together from the largely Islamic deserts of the Old World.

In a different sphere, camping, hiking, fishing and hunting are all popular in deserts among those seeking sunshine, warm weather, unusual landscapes and interesting plants and animals. For the same reasons, however, and encouraged by sparse vegetation cover, off-road vehicle use is also very popular in deserts (Lacher 1999). Use of dune buggies, dirt bikes, quad bikes and ordinary 4x4 vehicles produces noise, disturbs wildlife and destroys the soil surface and vegetation. Disruption of soil surface can lead to increased wind and water erosion, loss of organic material and compaction of soil which reduces water infiltration. Archaeological sites are particularly prone to destruction. On the gypsum plains of the coastal Namib desert, the rich lichen cover is eliminated by a single passage of an off-road vehicle and tracks

remain visible for decades if not centuries (Seely 2004). Gypsum plains and nearby dunes, including nesting sites of the endangered Damara Tern, are damaged every year during the "festive season" when hundreds of quad bikes descend on the small coastal desert resort of Swakopmund. The potential and ongoing impacts of off-road vehicles have led or are leading to increased management of public desert lands at many locations worldwide, although unclear jurisdictions and fear of revenue loss curtail many efforts (Figure 2.8).

The conservation of desert areas has had a chequered history and faces an unsure future. Deserts are often viewed as wastelands, uninteresting and useful for little more than perhaps prospecting and mining or military testing. In Namibia, the proclamation of the Namib-Naukluft Park had its origins in the colonial era when the Germans wanted to constrain the British to a small section of the coast at Walvis Bay. Decades of neglect followed as conservation efforts focused on areas where the expected big mammals of Africa are more common. Meanwhile, diamond, uranium and copper mines together with extensive prospecting and army activity left their indelible mark on the desert landscape. In the past several decades, the emphasis has shifted and Sossus Vlei, an ephemeral river terminating amongst the 300m high dunes of the Namib sand sea, is the second most visited tourism destination in the country. Transboundary parks, being negotiated with Angola and South Africa and occupying most of Namibia's coast, could mean varying degrees of conservation for the entire coastal Namib desert.

Figure 2.8: Desert vegetation patterns

Vegetation in desert plains often forms surprising and fragile patterns that are easily disrupted by motor vehicles. These enigmatic "fairy circles" are common on the sandy inland edge of the Namib Desert, and are a popular tourist attraction.

Source: Patricia Rojo

In North America, Joshua Tree National Park, 80 per cent of which is designated as wilderness area, contains portions of the Mojave and the Colorado deserts. Three main vegetation zones support diverse fauna (Braun 1999). Established in 1936 as a national monument, it was declared a national park in 1994. Death Valley is perhaps the most famous desert park in the United States (Hulett and Charles 1999a), with its name alone evoking visions of desolation and harsh landscapes. Nevertheless, it is a popular tourism destination with its historical and archaeological connections, endemic fish species, extremes of aridity interspersed with occasional massive flooding, geological diversity and striking landscapes. Major protected areas have been proclaimed in Australia, Mongolia and Oman and other desert countries of the world. They may focus on the landscape and biota, for example Joshua Tree National Park, the cultural relevance of the desert area, for example Saint Catherine's Monastery in the Sinai or Ayers Rock in Australia, or its seasonal support to pastoralists, for example in the Gobi Desert. Conservation of desert landscapes is expected to increase and, with growing use of environmental assessments and general environmental awareness, to be in greater harmony with ongoing extractive and currently destructive uses.

Conservation of deserts has gone hand-in-hand with desert tourism. Desert movies, desert books and other awareness-raising media have contributed to the tourism drive. However, desert tourism can be seen on a continuum with desert recreation and the mix is not always a happy one. Nevertheless, tourism is growing and expected to be the main means of generating income in many desert areas of the world. In Namibia and South Africa, community-based tourism is a rapidly growing sector involving people who were formerly struggling to make a living from the arid landscape (NACSO 2004). The potential for tourism growth, in terms of quality of experience and number of attractions and people experiencing these options, is huge.

Since the early days of the last century, if not before, desert research has held a special attraction for those who are interested in subjects ranging from geology to biology and from culture to religion all related to the extremes of desert environments. Some of the research efforts were small, one-person efforts, such as those of Felix Santschi who is identified as introducing to the scientific world sensory ecology based on his work with desert ants and ant navigation in Tunisia in the 1940s (Wehner 1990). Another was P.A. Buxton who first drew attention to the paradox of animal coloration in deserts and of so many black rather than the expected white beetles in the Palestinian desert (Buxton 1923). Large international research programmes, on the other hand, such as the International Biological Programme (IBP; 1966-1974) left a legacy in its multidisciplinary approach (Hulett and Charles 1999b).

Using a different, localised approach, Deep Canyon on the western edge of the Colorado Desert is associated with the University of California, Riverside located in the P.L. Boyd Deep Canyon Desert Research Center. It receives a variety of visiting scientists and students and, in addition to research, addresses conservation issues of the surrounding environment such as the fate of the fringe-toed lizard. Another desert centre established by one visionary biologist, the Gobabeb Training and Research Centre, is located in Namibia within the driest part of the coastal Namib Desert in the Namib-Naukluft Park.

People have lived in deserts for millennia, as hunter-gatherers, agriculturalists and pastoralists, and some people continue to do so today. But other people now live in urban developments situated in deserts, or enjoy deserts temporarily for tourism or recreation. Yet others are extracting profits from mining or other non-renewable resources. Deserts are a large and probably growing environment globally and their future will be best supported if it is based on a thorough understanding of their structure and function, and the influence of people's activities in the past, present and future.

REFERENCES

Abraham, E.M., and Prieto, M.R. (2000). Viticulture and desertification in Mendoza, Argentina. *Zentralblatt für Geologie und Paläontologie* 1(7/8): 1063–1078

Bean, L.J., and Saubel, K.S. (1972). *Temalpakh: Cahuilla Indian Knowledge and Usage of Plants*. Malki Museum, Banning, California.

Biesele, M. (1994). Bushmen of the Kalahari. In *Deserts* (ed. M. Seely) pp. 104–105. The Illustrated Library of the Earth, Weldon Owen, Sydney.

Bindon, P. (1994). People of the Australian Desert. In *Deserts* (ed. M. Seely) pp. 116–121. The Illustrated Library of the Earth, Weldon Owen, Sydney.

Bork, H.R., Bahr, J., Bork, H., Brombacher, M., Demhardt, I.J., Habeck, A., Mieth, A., and Tschochner, B. (2002). Development of the Oasis of San Pedro de Atacama, Chile. *Petermanns-Geographische-Mitteilungen* 146(5): 56–63

Braun, J.K. (1999). Joshua Tree National Park. In *Encyclopedia of Deserts* (ed. M.A. Mares) p. 316. University of Oklahoma Press, Norman.

Brookes, I.A. (1989). Above the salt-sediment accretion and irrigation agriculture in an Egyptian oasis. *Journal of Arid Environments* 17(3): 335–348

Broyles, B., Evans, L., Felger, R.S., and Nabhan, G.P. (2006a). Our Grand Desert: A Gazetteer. In *Dry Borders: Great Natural Reserves of the Sonoran Desert* (eds. R.S. Felger, B. Broyles). University of Utah Press, Salt Lake City.

Broyles, B., Rankin, A.G., and Felger, R.S. (2006b). Native Peoples of the Dry Borders. In *Dry Borders: Great Natural Reserves of the Sonoran Desert* (eds. R.S. Felger, B. Broyles). University of Utah Press, Salt Lake City.

Brunner, U. (2000). The Great Dam and the Sabean Oasis of Ma'rib. *Irrigation and Drainage Systems* 14(3): 167–182

Burrus, E.J. (1971). *Kino and Manje: Explorers of Sonora and Arizona*. Jesuit Historical Institute, Rome.

Buxton, P.A. (1923). *Animal Life in Deserts*. Edward Arnold and Co., London.

Castetter, E.F., and Bell, W.H. (1942). *Pima and Papago Indian Agriculture*. University of New Mexico Press, Albuquerque.

Castetter, E.F., and Bell, W.H. (1951). *Yuman Indian Agriculture*. University of New Mexico Press, Albuquerque.

Channell, R. (1999a). Domestic animals. In *Encyclopedia of Deserts* (ed. M.A. Mares) pp. 182–184. University of Oklahoma Press, Norman.

Channell, R. (1999b). Colorado River. In *Encyclopedia of Deserts* (ed. M.A. Mares) p. 129. University of Oklahoma Press, Norman.

Chatty, D. (1996). *Mobile pastoralists: development, planning and social change in Oman*. Columbia University Press, New York

Cleland, J.H., York, A., and Johnson, A. (2000). The tides of history: modeling Native American use of recessional shorelines. In *ESRI 2000 User Conference Proceedings*, ESRI, Redlands, California

Clotts, H.V. (1917). *History of the Papago Indians and history of irrigation, Papago Indian Reservation, Arizona*. Department of the Interior, United States Indian Service, Washington, D.C.

De Villiers, M. (2000). *Water*. Stoddart Publishing Co. Limited, Toronto.

Diamond, J. (2005). *Collapse: how societies choose to fail or succeed*. Viking, New York.

Dregne, H.E. (1999a). Nile River. In *Encyclopedia of Deserts* (ed. M.A. Mares) pp. 391–392. University of Oklahoma Press, Norman.

Dregne, H.E. (1999b). Tigris-Euphrates. In *Encyclopedia of Deserts* (ed. M.A. Mares) p. 561. University of Oklahoma Press, Norman.

Ebraheem, A.M., Riad, S., Wycisk, P., and Sefelnasr, A.M. (2004). A local-scale groundwater flow model for groundwater resources management in Dakhla Oasis, SW Egypt. *Hydrogeology Journal* 12(6): 714–722

Ezcurra, E., and Rodrígues, V. (1986). Rainfall patterns in the Gran Desierto, Sonora, Mexico. *Journal of Arid Environments* 10:13-28.

Felger, R.S. (2006). Living resources at the center of the Sonoran Desert: Native American plant and animal utilization. In *Dry Borders: Great Natural Reserves of the Sonoran Desert*. (eds. R.S. Felger, B. Broyles). University of Utah Press, Salt Lake City.

Felger, R.S., and Moser, M.B. (1985). *People of the Desert and Sea: Ethnobotany of the Seri Indians.* University of Arizona Press, Tucson.

Felger, R.S., and Nabhan, G.P. (1978). Agroecosystem diversity: A model from the Sonoran Desert. In *Social and Technological Management in Dry Lands. AAAS Selected Symposium 10*. (ed. N.L. Gonzalez) p. 128-149. Westview Press, Boulder, Colorado.

Fish, S. (2004). Corn, crops, and cultivation in the Greater Southwest. In *People and Plants of Ancient Western North America* (ed. P. Minnis) p. 115-166. Smithsonian Institution Press, Washington, D.C.

Fish, S., Fish, and P.R., Marsden, J. (1992). Evidence for large scale agave cultivation in the Marana community. *In The Marana Community in the Hohokam world.* (eds. S. Fish, P. Fish, J. Marsden) p. 73-87. University of Arizona Press, Tucson.

Flegg, F. (1993). *Desert: A Miracle of Llife*. Blandford, London.

Flint, R., and Flint, S. (editors and translators). (2005). *Documents of the Coronado Expedition, 1539-1542.* Southern Methodist University Press, Dallas.

Ford, R. I. (1983). Inter-Indian exchange in the Southwest. In *Southwest (ed. A. Ortiz) p. 711-722. Handbook of North American Indians,* vol. 10. Smithsonian Institution, Washington, D.C.

Gentry, H.S. (1982). *The Agaves of Continental North America*. University of Arizona Press, Tucson.

Golany, G. (1979). 'Israeli Development Policies and Strategies in Arid Zone Planning'. In *Arid Zone Settlement Planning: The Israeli Experience* (ed. G. Golany) pp. 3–42. Pergamon Press, New York

Gordon, R.J., and Douglas, S.S. (2000). *The Bushman Myth: The Making of a Namibian Underclass.* Westview Press, Oxford.

Halpern, E.A. (1999). Camel. In *Encyclopedia of Deserts* (ed. M.A. Mares) pp. 95–97. University of Oklahoma Press, Norman.

Haury, E.W. (1975). Shells. In *Excavations at Snaketown* (eds. H.S. Gladwin, E.W. Haury, E.B. Styles, N. Gladwin) p. 135-153. University of Arizona Press, Tucson. Reprint of 1938, Medallion Papers XXV, Gila Pueblo, Globe, Arizona.

Henschel, J.R., Burke, A., and Seely, M. (2005). Temporal and spatial variability of grass productivity in the central Namib Desert. *African Study Monographs* Suppl. 30: 43–56.

Henschel, J.R., Dausab, R., Moser, P., and Pallett, J. (eds). (2004). *!nara: fruit for development of the !Khuiseb Topnaar*. Namibia Scientific Society, Windhoek.

Hodgson, W.C. (2001). *Food Plants of the Sonoran Desert.* University of Arizona Press, Tucson.

Hulett, G.K., and Charles, A.R. (1999a). Death Valley. In *Encyclopedia of Deserts* (ed. M.A. Mares) pp. 147–148. University of Oklahoma Press, Norman.

Hulett, G.K., and Charles, A.R. (1999b). International Biological Programme. In *Encyclopedia of Deserts* (ed. M.A. Mares) pp. 301–302. University of Oklahoma Press, Norman.

Issar, A. (1999). The Past as a Key for the Future in Resettling the Desert. In *Desert Regions: Population, Migration, and Environment* (eds. B.A. Portnov and A.P. Hare) pp. 241–248. Springer Verlag, Heidelberg

Jacobsohn, M. (1994). Southern Africa – people of the Namib. In *Deserts* (ed. M. Seely) pp. 100–102. The Illustrated Library of the Earth, Weldon Owen, Sydney.

Kates, R.W., Johnson, D.L., and Johnson-Haring, K. (1977). Population, Society and Desertification. In *Desertification: Its Causes and Consequences* (ed. United Nations Conference on Desertification) pp. 261–318. Pergamon Press, Oxford

Kimber, R.G. (2005). 'Because it is our country': The Pintupi and their return to their country, 1970–1990. pp. 345–356. In *23°S Archaeology and Environmental History of the Southern Deserts*. National Museum of Australia Press, Canberra.

Kinahan, Jill (2000). Cattle for beads. *Studies in African Archaeology 17*. Uppsala University, Sweden and Namibia Archaeological Trust, Windhoek.

Kinahan, John (1991). *Pastoral Nomads of the Central Namib Desert: The People History Forgot*. Namibia Archaeological Trust & New Namibia Books, Windhoek.

Kinahan, John (2005). The late Holocene human ecology of the Namib Desert. In *23°S Archaeology and Environmental History of the Southern Deserts*. (ed. M. Smith and P. Hesse) pp. 120–131. National Museum of Australia Press, Canberra.

Lacher, T.E. Jr. (1999). Off-road vehicles. In *Encyclopedia of Deserts* (ed. M.A. Mares) pp. 396–397. University of Oklahoma Press, Norman.

Lancaster, W.O. (1981). *The Rwala Bedouin today.* Cambridge University Press, Cambridge

Louw, G., and Seely, M. (1982). *Ecology of Desert Organisms.* Longman, New York.

Lövenstein, H.M. (1994). Agricultural development. In *Deserts* (ed. M. Seely) pp. 151–155. The Illustrated Library of the Earth, Weldon Owen, Sydney.

Luedeling, E., Nagieb, A., Wichern, F., Brandt, M., Deurer, M., and Buerkert, A. (2005). Drainage, salt leaching and physico-chemical properties of irrigated man-made terrace soils in a mountain oasis of northern Oman. *Geoderma* 125(3–4): 273–285

Mares, E.A. (1999). Religion in deserts. In *Encyclopedia of Deserts* (ed. M.A. Mares) pp. 471–472. University of Oklahoma Press, Norman.

Marlett, C.M. (2005), Personal communication

Marx, E. (1977). Communal and individual pilgrimage: the region of saints' tombs in South Sinai. In *Regional Cults* (ed. R. Webner) pp. 29-54, Academic Press, Londonß

Marx, E. (1994). The Middle East. In *Deserts* (ed. M. Seely) pp. 110 –115. The Illustrated Library of the Earth, Weldon Owen, Sydney.

McGuire, R.H., and Schiffer, M.B. (editors). (1982). *Hohokam and Patayan: Prehistory of Southwestern Arizona.* Academic Press, New York.

Montaña, E, Torres, L., Abraham, E.M., Torres, E., and Pastor, G. (2005). Los espacios invisibles. Subordinación, marginalidad y exclusión de los territorios no irrigados en las tierras secas de Mendoza, Argentina. *Región y Sociedad* (El Colegio de Sonora, México) 17(32): 4–32

Moore, K.M., Miller, N.F., Hiebert, F.T., and Meadow, R.H. (1994). Agriculture and herding in the early oasis settlements of the Oxus civilization. *Antiquity* 68(259): 418–427

Nabhan, G.P. (1985). *Gathering the Desert*. University of Arizona Press, Tucson.

NACSO. (2004). *Namibia's Communal Conservancies: A Review of Progress and Challenges.* NACSO, Windhoek.

Ngaido, T., Shomo, F. and Arab, G. (2001). Institutional change in the Syrian rangelands. *IDS Bulletin* (Institute of Development Studies) 32(4): 64–70

Ocampo, O. (1999). Movies in deserts. In *Encyclopedia of Deserts* (ed. M.A. Mares) pp. 378–382. University of Oklahoma Press, Norman.

Pailes, R.A. (1999). Desert peoples. In *Encyclopedia of Deserts* (ed. M.A. Mares) pp. 156–167. University of Oklahoma Press, Norman.

Parrish, A.M. (1995). 'There were no sus in the old days:' post-harvest pest management in an Egyptian oasis village. *Human Organization* 54(2): 195–204

Portnov B.A., and Safriel, U. (2004). Combating desertification in the Negev: dryland agriculture vs. dryland urbanization. *Journal of Arid Environment* 56(4): 659–680

Portnov, B.A., and Erell, E. (1998). Long-term Development Peculiarities of Peripheral Desert Settlements: The Case of Israel. In *International Journal of Urban and Regional Research* 22(2): 216–32

Rea, A.M. (1981). Resource utilization and food taboos of Sonoran Desert peoples. *Journal of Ethnobiology* 1:69-83.

Rea, A.M. (1983). *Once a River: Bird Life and Habitat Changes on the Middle Gila.* Tucson: University of Arizona Press.

Rea, A.M. (1997). *At the Desert's Green Edge: An Ethnobotany of the Gila River Pima*. University of Arizona Press, Tucson.

Reader, J. (1997). *Africa: A Biography of the Continent*. Penguin Books, London.

Reisner, M. (1986). *The Cadillac Desert: The American West and its Disappearing Water*. Penguin, New York.

Roig, F.A., Gonzalez-Loyarte, M., Abraham, E.M., Méndez, E., Roig, V.G., and Martínez Carretero, E. (1991). Maps of desertification hazards of Central Western Argentina (Mendoza Province). In *World Atlas of Thematic Indicators of Desertification* (ed. UNEP). Edward Arnold, London

Saini, B. S. (1980). *Building in Hot Dry Climates,* John Wiley & Sons, Chichester

Sandelowsky, B.H. (1974). Archaeological investigations at Mirabib Hill rock shelter. *The South African Archaeological Society Goodwin Series* 2: 65–72.

Seely, M. (2004). *The Namib: Natural History of an Ancient Desert.* DRFN, Windhoek.

Shackley, M. (1980). An Acheulean industry with *Elephas recki* fauna from Namib IV, South West Africa (Namibia). *Nature* 284 (5754): 340–341.

Shackley M. (1983). Human burials in hut circles at Sylvia Hill, S.W. Africa/Namibia. *Cimbebasia Series B* 3 (3): 102–106.

Shreve, F. (1951). *Vegetation of the Sonoran Desert.* Carnegie Institution of Washington Publication No. 591. Reprinted 1964, part 1 of F. Shreve, I. L. Wiggins, *Flora and Vegetation of the Sonoran Desert.* Stanford University Press, Stanford.

Smith, A.B. (1994) African desert people: North Africa. In *Deserts* (ed. M. Seely) pp. 94–98. The Illustrated Library of the Earth, Weldon Owen, Sydney.

Smith, M., and Hesse, P. (eds) (2005). *23°S Archaeology and Environmental History of the Southern Deserts.* National Museum of Australia Press, Canberra.

van den Eynden, V., Vernemmen, P., and van Damme, P. (1992). *The Ethnobotany of the Topnaar*. Universiteit Gent.

Wang, B.C., Qiu, H.X., Xu, Q., Zheng, X.L., and Liu, G.Q. (2000). The mechanism of groundwater salinization and its control in the Yaoba Oasis, Inner Mongolia. *Acta Geologica Sinica*-English Edition 74(2): 362–369

Wehner, R. (1990). On the brink of introducing sensory ecology: Felix Santschi (1872–1940) – Tabib-en-Neml. *Behavioural Ecology and Sociobiology* 27:295–306.

Wrigley, G. (1995). Date palm *Phoenix dactylifera*. In *Evolution of crop plants,* 2nd ed. (eds. J. Smartt and N. W. Simmonds) pp. 399-403. Longman, Harlow, UK

Zohary, D. and Hopf, M. (2000). *Domestication of plants in the Old World* 3rd ed. Oxford University Press, Oxford, UK