

Adaptation of Animals to Arid Ecological Conditions

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INTRODUCTION

Deserts generally come into the arid zones of the world, although there are some arid areas that are not necessarily deserts, (like the arid zones of the tropics). The arid zones of the world are not less than 18 million Sq. Km. since then world deserts extend to approximately 18 million sq. Km. [1]. Deserts are areas where the annual rainfall averages less than 250mm. The principal deserts of the world include those in Asia (Arabia, Turkestan, Mongolis, Pakistan and China); Africa (Sahara and Namib); Americas (South United States, Peru, Chile and Central Australia).

The predominant feature of all deserts is the scarcity of vegetation which never covers more than 50% of the whole surface. Temperature fluctuates. There is general distinction between cold and hot deserts.

There are three arid regions in tropical Africa referred to as the Sudanese, Somalia and South-West arid zones extend beyond the limits of the tropics. The Sudanese zone lies North of about 12°N and extends from Mauritania and Senegal in the West to Sudan in the East and includes the Sahara Desert.

The Somalia arid zones comprises the coastal regions of Ethiopia, Somalia and Kenya and it is connected with the Sudanese arid zone along the Red Sea Coast. The third region comprises the Namib and Kalahari deserts of South Africa, South West Africa and Botswana. Balinsky [2] thinks that it is probable that the South West arid zone was linked to the Sudanese arid zone in the past along a 'drought corridor' but now the South West arid zone is isolated from the arid zones North of the Equator. Delany and Happold [3] have said that the arid zones of tropical Africa are basically flat with some isolated granitic hill masses called jebels or insalberg (in the North) or Koppies (in the South). Some of the jebels are dissected with

cracks and gullies, some have deep crevices and caves. Large sand ridges occur in some localities. Water courses (Wadis, Khora) cross the sand plains, but they are usually dry except for a few hours after heavy rainstorms. The soils of the arid zones are normally shallow and almost entirely lacking in organic matter.

In this paper, a close look will be made into two localities viz the Sudanese sand plain near Khartoum and the Kalahari Gemsbok National Park. Near Khartoum there are a few large sand dunes locally known as 'qoz'.

The River Nile flows Northwards through the sand plain but the mosaic conditions of the river do not extend more than a few meters beyond the river bank. The Kalahari Gemsbok National Park consists of extensive 'sandveld' of sand dunes interspersed with pans and depressions of hardened sand and soil. This habitat covers about 90% of the Park. The Nossots and Auob Rivers dissect the sandveld. In both localities temporary pools of water occur in the river beds and sand plain after heavy storms.

Climate: The desserts of Central Asia have a typically continental climate with very low temperature in winter and generally hot summers. Throughout the arid zones of tropical Africa, the annual potential evapotranspiration is at least twice as great as the annual rainfall. Characteristically, the annual rainfall is very variable and in most arid regions long periods of drought are not uncommon, [3]. At Khartoum, the average annual rainfall is about 150mm. but the actual rainfall varied from 50mm per annum during the years 1940 to 1960 [4]. Rainfall in the arid regions is extremely localized so that places a few kilometers apart may have varying amounts of rain and storms at different times. Delany and Hoppoid [1] held that the average rainfall is 226mm in the Kalahari. Comparing they conclude that although the average

annual rainfall is higher than in Khartoum, the months of heaviest rainfall in the Kalahari have less rain than the months of heaviest rainfall at Khartoum; and the rainfall is distributed more evenly throughout the year. Rainfall is very sporadic asserts [5] and although the average rainfall in April, for example is 44mm, the range varies from 0mm. to 100mm.

There are seasonal and diurnal fluctuations in temperature with hot days and cool nights in African arid regions. In the dry seasons both maximum and minimum daily temperatures are lower than those in the wet seasons. It appears that the months of highest rainfall are associated with a fall in temperature fluctuations in the Kalahari Gemsbok National Park are similar to those at Khartoum except in two important respects. The coolest months are in May - August, instead of December to February; because the Kalahari is in the Southern Hemisphere and the mean temperatures are cooler in Kalahari Gemsbok National Park so that in the hot season the maximum temperatures are rarely above the lethal limits for mammals and in the cool season sub-zero temperatures are not uncommon.

There is absence of clouds and because vegetation is scarce, there is practically no shade, insulation is the result. Consequently range of shade temperatures as recorded by conventional meteorological stations is by far less than the range of temperatures in the open. The soil at ground level heat rapidly during the day and loses heat rapidly at night.

In Khartoum, the temperature 1cm. below ground level may fluctuate as much as 35°C from a maximum of 65°C at about 1400hrs L. M. T. to a minimum of 30°C just before sunrise [4]. However, since the soil is a good insulator diurnal fluctuations decreases with depth. Many arid zones animals burrow to depths of 50-100m. where diurnal fluctuations in temperature is less than 1°C. The annual range of temperatures also decrease with depth.

Also typical of tropical arid zone climates is low relative humidities. The occurrence of rain and some seasonal variations related to the movement of the inter-tropical convergence zone (ITCZ) exist. Relative humidity is highest just before sunrise and lowest at about 1600hrs [3]. High temperatures and low relative humidities result in high rates of evaporation from open water and or moist soil.

This, as well as the low unreliable rainfall and the absence of springs and rivers, result in the aridity which is the major problem for animals and plants in the arid zones.

Vegetation: The vegetation of an area depends largely on the climate and the geophysical properties of the area. Consequently the carrying capacity of the arid zones is primarily related to the state of the vegetation; since plants provide mammals with food and shelter and water in the case of the arid zones. Plant life is sparse in arid regions mainly because of the lack of water and therefore the density and distribution of the vegetation is related to rainfall and geomorphology. Rainfall run-off collects at bases of jebels, in depressions and in water courses. These localities support xerophytic plants, whose deep roots draw moisture from the ground water many meters below the surface and drought-enduring plants which are dormant in the dry season and begin growth from rootstocks or rhizomes after rain. [3]. In localities where water does not collect, there are many species of desert grass and herbs which appear only after rainstorms. These ephemeral drought-evading plants germinate, grow, flower and set seed within 3-4 weeks before the upper layers of the soil dry again [6].

The wadis of the regions near Khartoum are reported to contain clumps of perennial grasses *Panicum turgidum* and *Cymbopogon proximum* and small trees of *Acacia* Spp; *Balanites aegyptiaca* and *Commiphora africana* – Other shrubs, grasses and climbers may also be present; but succulents are rare.

There could be great variation in vegetation composition of the arid zones and this would depend on locality and topography as recorded for Kalahari Gemsbok National Park by Delany and Hoppold [3]. On the sandveld, especially on the crests and rises of the dunes, there are scattered *Acacia*, *Grewia*, *Boscia*, *Albitnica* and *Terminalia sericea* bushes and shrubs clumps of *Aristida*, *Eragrostic* and *Athenatherum* grasses grow on the dunes but shrubs and grasses are absent or rare in the troughs between the dunes. The river beds and banks support an entirely different and richer flora due to the generally higher moisture content of the soils and the mosaic of different soil types [3].

Plants which appear to be important sources of water, particularly in the dry season, are *Citrellus* spp (fruits and seeds); *Cucumis* spp (fruits) *Elephantorrhiza* (roots) *Crinum* (bulbs) and *Oxygonum delagoense* (stems and leaves).

After rains, for example two showers of 12mm or more within 2 or 3 weeks, ephemeral plants germinate and grow on the sandveld providing a luxuriant, though temporary, source of food for many mammals [7, 8].

Some Animals of the Arid Zones: The sole business of living things is to survive. Both plants and animals have therefore evolved very many and varied forms of adaptation in order to still thrive. As ecological conditions vary so do biotic and abiotic factors of any environment vary. Consequently the different ecological conditions have given rise to different ecological zones of which the arid zones form part. Each ecological zone has both vegetation and animals typical to it. Common desert animals include the rodents which are handy at digging and always building up food reserves as is the case with jumping mice of the genera *Rhombomys* and *Spermophilopsis*. The best known rodents both in Asia and other deserts are the family Dipodidae, many of which can move extremely fast [1]. A species of rodent feeding exclusively on insects was discovered in 1938 in the desert of Kaza Khstan. This is the unique selevin mouse (*Selevinia betpakadalaensis*). Taglianti [1] records that several races of hare are also found in the deserts. Among ungulates is the goitred or Persian Gazella (*Gazella subquitturosa*) which can race along at 80km. p.h.

With the carnivore, the sand cat (*Felis marqarita*), the desert Fox (*Vulpes corsac*) and a strange mustelid, the marbled polecat *Vormela peregusna* are representatives. There seems to still remain a wild population of Bactrian Camel (*Camelus bactrianus*) thinks Taglianti [1].

Fifteen species of mammals have been reported to occur in the sand plains near Khartoum. There are also some non-arid zone species, e.g. Nile rat (*Arvicanthis niloticus*) white tailed mongoose (*Ichneumia albicauda*) genet (*Genetta genetta*) and fruit bat (*Eidolon helvum*), living in the Nile valley, their presence according to Happold [9] shows that non-arid spp. Can penetrate into the arid zones if tracts of suitable habitat are present.

Adaptation of Animals to the Arid Zone: Some desert animals are capable of existing entirely without water. They generally possess sandy colouration, some have long claws and long hair which help to prevent sinking into the deep sand and also provide efficient insulation against heat. Many of these adaptations are concerned with survival when food and water are scarce and when the environmental temperature reaches the upper limits of tolerance. Others are concerned with the ability to reproduce rapidly and to put the maximum energy into reproduction when conditions are favourable. These adaptations can best be classed as morphological, physiological and social.

Availability of Food: The amount of food available for mammals varies from time to time and from place to place because of the varying effects of rainfall, topography and season on vegetation. Arid zone mammals attempt to survive fluctuating food resources in several ways; some travel long distances from poor areas into richer ones, some store food and others change their diet.

The Scimitar-horned Oryx and Gemsbok, Addax and Ducas Gazelle are examples of nomadic arid zone mammals. Addax are recorded as being able to detect changes in humidity of the air so they can find areas where grass is sprouting after a rain storm. The ability to travel and migrate long distances is essential for the survival of these mammals because of the widespread, sporadic availability of suitable foods. Small non-migratory mammals are unable to escape from harsh environmental conditions and therefore their population numbers are subject to considerable fluctuations. Mammals also hoard food when supplies are plentiful. It has been recorded that *Gerbillurus pyramidum* at Khartoum [9] and *Desmodillus auriculavis* [10] and *Gerbillurus paebe* [11] in the Kalahari Gemsbok National Park, hoard food for use in times of shortage *Xerus erythropus*, the ground squired which lives in the Sudanese and Somalia arid zones also buries food for future use [12].

The last method of surviving fluctuating food resources is to change diet or eat a wide variety of foods. This is specially practiced by the carnivorous and insectivorous mammals whose prey numbers fluctuate erratically. Monad [13] found that fennec foxes have a mixed diet of insects, lizards, rodents and plant.

Availability of Water: In the arid zone, the limited rainfall means that there is no free water for most or all of the year and mammals have to obtain water from their food by metabolism. Throughout most of their lives, arid zone mammals survive on very little water and many characteristics of their anatomy, physiology and behaviour facilitate conservation of body fluids.

Schmidt-Nielsen [13] records such adaptations in arid zone mammals as shortage of water in the camel, ability to eat saline succulents in the rodents *Psammomys*, reliance on high water content of succulents (*Trianthema*) which obtains its moisture from advective fog in the Namib desert [3]; migratory movements to search for green forage and or water and many physiological characteristics of the kidneys, skin and blood system. Arid zone carnivores obtain most of their water from the body fluids of their

prey. It has been reported that the spotted hyaena (*Crocuta crocuta*), the black-backed jackal (*Canis mesomelas*) and some small rodent feed extensively on the workers of harvester termites (*Hodotermes mossambica*) which emerge after rain [3].

Temperature: Temperature in the arid zone could be so high as to approach and sometimes exceed, the limits of tolerance of most mammals. Large mammals which because of their size have to remain on the surface of the ground, shelter in shady areas and some (e.g. the Camel) are able to withstand an increased body temperature provided this extra heat load can be lost during the night. Cooling mechanisms which depend on the evaporation of water, such as sweating, panting and licking, are infrequently used because water is scarce. However water loss by evaporation many take place, for a short period of time, if the body temperature reaches a particular upper limit.

Small mammals burrow or shelter in caves where the maximum daily temperature and the daily range of temperature, is less than that of the air. After sunset as the air temperature is falling, foxes, weasels, hedgehogs, rodents and bats emerge from their resting places. Their burrowing or cave-dwelling behaviour during the dry and nocturnal activity on or above the surface, reduces the range of temperatures to which they are exposed. This is a very essential behavioural characteristic for small mammals as they are unable to survive long exposures to the typically high temperatures of the surface sand and the air during the day [3].

At nights cold temperatures are experienced and these temperatures may be lethal to small mammals, rodents tend to be rather inactive on cold nights as a result.

Reproduction: The perpetuation of a race is the only evidence that the various adaptive strategies have worked. So animals must survive and reproduce. Since the resources of the arid zone are not regular and are unpredictable, it is not an advantage for animals to have a regular breeding season. Characteristics which allow rapid reproduction when conditions are 'right' so as to produce the maximum number of weaned young in the minimum time, will result in a population which is sufficiently large that some individuals should survive condition (say drought). Such characteristics include a social organization which reduces competition for mates, a short-gestation period, rapid growth of the young to

weaning age, a post-partum Destrus so a second litter can develop while the former litter is sucking and the storage of food to supply readily available energy when reproduction begins. Small mammals population recover quickly after drought periods due to their rapid reproductive rates.

Large mammals are less numerous in the arid zones due to the scarcity of food and because of their greater longevity they do not need to produce as many young in order for the population to survive. Here it does not seem that populations of large mammals will increase or decrease in exact synchrony with the carrying capacity. It appears that populations of large species survive, not because of rapid reproduction, but because of their longevity, mobility to search for food and because some food resources last for a long time due to a low rate of utilization.

Physiological Adaptations: Adaptations could take the various forms as controlled by morphology, physiology and sociology of the species in question. In the arid zones as well as other ecological zones of the world, physiological adaptations seem to command more importance than any other. In fact for any other form of adaptation to be successful the physiology of the plant or animal must count. In physiology, water, salt and temperature regulation are involved.

Body fluids have to be conserved because a reduction of body fluids below about 80 percent of normal is lethal for most species. In the arid zones where water shortage is most likely, the individual also has to cope with high ambient temperatures in the day time. If water is scarce many mammals can reduce their daily minimum water requirements so that the turn-over rate of fluids in the body is also reduced. Body fluid conservation may be by means of:

- Production of concentrated urine so that only a small volume of water is lost during the elimination of urea.
- Reduction of the volume of water in the faeces.
- Reduction of evaporative water loss by:
 - a. The ability of the individual to survive an increase in its body temperature so that water need not be used to maintain a constant body temperature.
 - b. Activity rhythms and behaviour patterns which enable the individual to remain in the coolest and most moist micro-environment in its habitat.
- The ability to withstand desiccation and reduction in the extra-cellular and intracellular fluids in the body.

- The ability to locate sources of free drinking water, to change the diet as conditions require and to eat saline food if necessary.

An unusual method of maintaining water balance is illustrated by the sand rat (*Psammomys obesus*), which the ability to feed on juicy saline plants of the family *Chenopodiaceae*. The distribution of sand rats in the arid regions in Africa North of the Equator, is determined to a large extent, by the presence of these plants [3]. Sand rats are able to eliminate the excess salts in the urine which is at least as concentrated as the sap in the plants [13]. The urine is about four times as saline as sea water and although the urea concentration is not particularly high, the urine electrolytic concentration (1920m Eq/L) is the highest recorded from any mammalian kidney.

Maximal urine concentration recorded in rodents [13].

Species	Urine urea mM/L	Urine electrolyte mEq/L
<i>Gerbillus qerbillus</i>	3410	1600
<i>Jaculus jaculus</i>	4320	1530
<i>Psammomys obesus</i>	2850	1920
White rat	2160	760

The kidneys of *Jaculus jaculus* and *G. qerbillus* have long renal papillae which project into the water, this gives maximum reabsorption of water in the kidney and helps to produce a concentrated urine [14, 15]. In *J. jaculus* there is a special arrangement between the cortical and juxtamedullary glomeruli which results in a large filtration area [16] and therefore the production of highly concentrated urine.

A specialized form of heterothermy is shown by a few species of large African mammals which are normally homeothermic; (Delany and Happold 1979) these species exhibit hyperthermia when the body temperature which would be lethal for most mammals. This unusual characteristic enables large species to survive in arid regions with high day time temperature. The actual range of body temperature is species-specific and in heterothermic species is related to the ambient temperature of the environment (or micro-environment) where the spp. Live.

The body temperature is also related to the overall energy budget of the individual because homeothermy requires a constant expenditure of energy.

In the regulation of body temperature, the climate factors as well as the sp. of mammals have resulted in varied strategies.

- Behaviour and activity patterns reduce the effects of stress resulting from high or low ambient temperatures.
- The density and colour of the hair or fur determine the amount of heat which is absorbed through the body surface. It also regulates heat loss by thermal conductance away from the body surface.
- Many spp. have emergency methods of cooling the body (Salivation, licking the fur, exposing the maximum body surface to the surrounding air.
- Excess heat load is usually dissipated by evaporative water loss.
- Some spp. tolerate a widely fluctuating body temperature which changes in relation to ambient temperatures (400°C or more) by allowing the body temperature to rise above normal for several hours at a time.

In all mammals the methods of temperature regulation are closely associated with the availability of water and it is often difficult to discuss temperature regulation independently from water metabolism.

CONCLUSION

Nature has ensured that living things will utilize all the available resources, this is possible through natural selection. The adaptive radiation which is so frequently encountered in the study of nature only buttress this fact. Animals and plants get adapted in order to survive. They also do sometimes to avoid competition as shown by the sand rats above. The environment or ecological zone has influence on the various adaptations required. Adaptations could be physiological, morphological and social. Adaptations could be temporary and innate.

So arid zone animals have to cope with water scarcity and extreme temperatures, lack of shade and harsh relative humidity. They therefore, migrate, burrow, hoard food, engage in rapid reproduction and endure large fluctuation in temperature. But they still survive and there is even a wild population of the domesticated few.

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