ECOLOGY OF THE INDIAN DESERT GERBIL, *MERIONES HURRIANAE*

By
ISHWAR PRAKASH

ICAR

CENTRAL ARID ZONE RESEARCH INSTITUTE
JODHPUR

ECOLOGY OF THE INDIAN DESERT GERBIL, *MERIONES HURRIANAE*

By
ISHWAR PRAKASH

ICAR

CENTRAL ARID ZONE RESEARCH INSTITUTE
JODHPUR

SEPTEMBER 1981

CAZRI Monograph No. 10

Published by the Director, Central Arid Zone Research Institute, Jodhpur and Printed at the Harvard Press, Jodhpur 342003.

CONTENTS

FOREWORD

Deserts are perpetually scarcity biomes. Even under natural conditions deserts have a rather fragile ecological balance; even a slight disturbance by man can disturb this balance. The Indian Arid Zone is even more vulnerable since it is one of the most populated deserts of the world and it faces severe pressures of increasing human and livestock populations. Rodents further aggravate the desertification processes by depredating upon the sparse vegetation and disturbing the soil through their fossorial propensity. Due to their sheer numbers and omni-presence in almost all the desert habitats, they have assumed a severe pest problem. Rodents are physiologically and behaviourally well adapted to climatic vagaries and fluctuations in food supply. Realising their potential as one of the desertification factor, CAZRI initiated intensive studies in early sixties on vertebrate pests of the Indian Arid Zone. The CAZRI has been designated as the National Coordinating and Monitoring Centre for Rodent Research and Training in the Country.

I am glad that Dr. Ishwar Prakash has collated and compiled his work on the Desert Gerbil, *Meriones hurrianae*, a predominant rodent in the Indian Arid Zone. This monograph is one of the first detailed work on a single vertebrate species in India. I congratulate Dr. I. Prakash for his intensive studies on this important desert species and for his efforts to publish this work.

7 July 1981

H. S. MANN
Director
Central Arid Zone Research Institute,
Jodhpur.

PREFACE

Even at this distance of time, I can clearly recapitulate that in the years 1950-52, during my long walks through the desert from the hostel to Birla College, at Pilani, I used to watch scores of little Indian desert gerbils either sitting close to their burrow openings, or nibbling, foraging and chasing each other in a playful manner. The tiny rodent fascinated me so much that when I joined a UNESCO Project to study the ecology of Indian desert mammals, and later at CAZRI, it naturally received the lions share of my own and my colleagues' attention. In the course of time, our research interest in this rodent has only deepened as newer knowledge on desert survival itself could be generated from a study of this animal. A number of research papers emanating from these studies have appeared in various journals describing ecological, behavioural, physiological, toxicological and control aspects. It may not sound prudish, but it is a fact that my prolonged interest has raised the status of the Indian desert gerbil, *Meriones hurrianae*, to that of the most studied mammal of the Indian sub-continent, i.e. besides man. However, I am aware that a good deal more about this 'most-studied' rodent awaits to be known, and we are making serious efforts in this direction.

In the course of my studies on the gerbil, I have received guidance, encouragement and unstinted support from Prof. Daya Krishna, the late Dr. P. C. Raheja (1952-1964) and Dr. H. S. Mann (1971-continuing) and I express my gratitude to them. To my colleagues, Drs. P. K. Ghosh, C. G. Kumbkarni, K. G. Purohit, B. D. Rana, B. S. Gaur, A. P. Jain, R. Advani, R. P. Mathur, Saroj Kumari and B. K. Soni, whose works have also been summarised in this monograph, I am grateful for their wonderful collaboration. Dr. A. M. K. Mohana Rao, Shri S. P. Goyal and Shri Devendra Bhardwaj assisted me in this compilation and my special thanks are due to them. The Cartography Section of CAZRI and Shri A. K. Sen were always found ready for making the drawings for this monograph. The manuscript was carefully typed by Shri T. S. Viswanathan. I am grateful to all of them. Thanks are also due to editors of Journal of Bombay Natural History Society for permitting me to reproduce excerpts from our papers published in the Journal.

Dr. H. S. Mann, Director, CAZRI, supported the entire project morally, financially, and by providing all the facilities. Dr. Pulak Ghosh, Head of the Division of Animal Studies, CAZRI, my friend indeed, was with me to provid moral strength which was needed at times. I am deeply indebted to them.

7 July 1981

ISHWAR PRAKASH
Coordinating & Monitoring Centre for Rodent Research and Training, Central Arid Zone Research Institute, Jodhpur.

INTRODUCTION

The mammalian fauna of India is better known than that of several Afro-Asian countries. At the dawn of the present century an immense volume of material poured out of the pens of stalwarts of Indian mammalogy like W.T. Blanford, T. C. Jerdon, R. C. Wroughton, O. Thomas, followed by R. I. Pocock, S. H. Prater and J. R. Ellerman. The Bombay Natural History Society did a great service by conducting mammal surveys of the Indian sub-continent. Unfortunately, however, neither the survey teams visited the Rajasthan desert nor its fauna was studied during the golden period of Indian mammalogy. The author had, however, the privilege of initiating research work on the desert vertebrates under the auspices of a UNESCO Project (1952-56) with the able guidance of Prof. Daya Krishna. Later, in 1959, the Central Arid Zone Research Institute created opportunities for studies on the fauna of the Indian arid zone by organising a section on Animal Ecology. As a result, several monographic works on the vertebrates of Rajasthan desert have appeared (Fitzwater and Prakash, 1966, 1974, 1978; Prakash, 1957, 1959, 1974, 1975, 1977; Prakash *et al.*, 1971a; Prakash and Ghosh, 1975; Gupta and Prakash, 1975; Barnett and Prakash, 1975; Reichman *et al.*, 1979). The present monograph is an attempt to collate and compile the results of work carried out on the eco-physiological aspect of *Meriones hurrianae* by the author during the last 27 years, along with those of his colleagues, and the information available in a scattered way in numerous scientific periodicals on the most abundant and destructive mammal of the Indian desert, *Meriones hurrianae* (Jerdon).

The Study Area

The Rajasthan desert, which has been the venue of our studies since 1952, is a land locked tropical desert situated on the eastern most fringe of the Saharo-Rajasthanian belt. Its eastern boundary coincides with the Aravalli ranges which continue into wooded land further to it. Archaeologically, this desert is not very old as its age is estimated to be 5,000-10,000 years (Krishnan, 1952; Wadia, 1960), though contradictory views have been expressed by various authors on its age (Ahmed, 1969).

Rajasthan desert, occupying about 60 per cent of the total Indian arid region, lies between 25° and 30° North Latitudes and 69.5° and 76° East longitudes. The rainfall, as characteristic of desert is low and erratic. Ninety per cent of it falls during the monsoon season, from July to September. It varies from 80 mm to 425 mm per annum (Range during 50 years). During the period of study (1968-69) the rainfall varied from 9 to 200 mm at various localities in the Rajasthan desert. Heat during the summer is intense. The average monthly minimum and maximum temperatures available for some stations are recorded in Table 1. Relative humidity is minimum during the hot season, while it is maximum during the monsoon; April and August are recorded as the months with lowest and highest humidity respectively (Pramanik and Hariharan, 1952). The mean vapour pressure values are lowest during the cold season and maximum during monsoon season.

The habitats have been classified into sandy, gravel, rocky and ruderal following Prakash (1962-64). The sandy habitat covers vast stretches of loose sand transported by high wind velocity, sometimes forming hummocky phase and sand sheets on the alluvial plains in varying thickness. The sandy plains are interspersed with mobile sand dunes in the crop fields. Where irrigation facilities are available the land is put to agricultural use regularly, otherwise the land is kept fallow ranging from 2 to 3 years to regain soil fertility. The gravel plains are usually situated on the foothills save in Jaisalmer district where vast gravel plains occur even without the presence of hills in the near vicinity. This type of habits does not, however, occur in all the districts. Rocky outcrops occur throughout the region but are notable in Sirohi, Jalore, Jodhpur, Jaisalmer and Jhunjhunu districts where the studies were conducted. These rocks are a mixture of rhyolite and sedimentary sandstone. The crevices and shallow caves on the hills and *Euphorbia caducifolia* clumps on the hilly slopes form the ideal habitats for rodents. Village settlements are scattered throughout the desert on almost all the landforms depending upon the availability of water. This complex situation, the ruderal habitat, was studied in all the districts. Almost all of these areas are rainfed and irrigated crops are situated very near the human dwellings. Field and house boundaries made of mud wall covered with dry thorns of *Zizyphus nummularia*, *Prosopis juliflora* and twigs of *Calligonum polygonoides* form an ideal habitat for the rodents in this habitat.

Table 1. Mean maximum and minimum temperature (°C), rainfall (mm) and relative humidity (per cent) at 17 hrs. (IST) in some of the localities in the Rajasthan desert

Stations		Jan.	Feb.	March	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Yearly average
Sri Ganganagar	I	19.8	23.1	28.3	35.2	42.1	41.6	38.9	37.7	37.8	35.1	29.1	23.1	32.7
	II	3.4	7.6	11.2	16.7	23.9	27.4	28.1	26.9	23.4	15.4	8.7	4.0	16.7
	III	6.6	11.2	5.3	5.1	6.1	31.0	68.3	70.6	6.9	1.5	0.0	5.3	217.9
	IV	42	41	31	23	20	31	43	45	47	28	32	39	34
Jodhpur	I	24.6	27.0	32.5	37.4	40.8	39.8	36.1	33.2	34.6	35.3	30.9	26.1	33.2
	II	9.2	11.4	16.4	21 6	26.3	27.9	26.8	25.0	23.8	18.6	13.0	10.3	19.2
	III	3.8	6.1	2.8	3.3	10.4	36.1	100.8	122.9	62 0	8.2	2.8	2.8	360 9
	IV	22	21	17	11	15	34	46	50	40	16	18	22	27
Jaisalmer	I	23.8	25.4	31.7	38.5	42.8	40.4	37.7	34.7	37.7	35.6	30.4	24.8	33.6
	II	8.9	8.9	16.9	21.4	26.8	26.8	26.8	24.9	25.1	19.5	11.3	6.2	18.7
	III	4.1	4.8	3.6	2.8	7 9	14.7	52.3	62.5	21.8	1.3	1.3	2.0	179.1
	IV	45	25	35	37	32	44	65	73	64	29	23	21	41
Barmer	I	24.7	27.4	32.3	37.9	41.3	39.7	35.8	33.6	35.1	36.2	31.9	27.3	33.6
	II	10.0	13·1	17.9	23.5	26.7	26.8	26.1	24.9	24.3	21.3	16.1	11.9	20 2
	III	2.5	3.6	3.1	1.5	9.4	24.6	89.4	86.6	37.1	2.5	1.3	1.8	263.4
	IV	28	28	30	25	37	40	51	51	44	29	26	28	34
Sikar	I	22.7	24.8	31.0	37.6	42.2	40.6	36.2	33 5	34.2	34.2	29.2	23.9	32.5
	II	6.9	7.5	14.2	20.3	26.7	28.6	26.4	24.6	23.1	17.6	8.9	5.3	17 5
	III	9.1	8 4	7.6	2.8	16.3	46.7	126.7	147.3	49.3	6.1	3.6	6.9	430.5
	IV	34	24	21	15	20	25	74	60	50	28	30	38	35

After Pramanik Hariharan (1952). — I = Mean maximum temperature; II = Mean temperature; III = Mean rainfall; IV = Mean relative humidity.

TAXONOMY, DIAGNOSIS AND GEOGRAPHICAL DISTRIBUTION

The genus *Meriones* Illiger, 1811 (Muridae, Gerbillinae) has a wide range of distribution from Morocco in northwestern Africa to the Indian desert in the east and through the Russian and Chinese deserts to Gobi in Mongolia and Manchuria in north. The taxonomic treatment of the genus is available in Thomas (1919), Ellerman (1940, 1941, 1947), Chawor h Musters and Ellerman (1947). The genesis is characterised by upper molars being strictly simple prismatic with no signs of cusps. The folds of the upper molars are most'y equal in size. Laminae of molars are joined, and the folds nearly meet in the middle line of the tooth (El'erman, 1961). With these characters the genus can be differentiated from the two other genera viz. *Tatera* and *Gerbilus* of the subfamily Gerbillinae found in the Indian subcontinent. The Indian Desert Gerbil, *Meriones hurrianae* (Jerdon, 1867) is the eastern-most species of the genus in the Saharo-Rajasthan desert range (Prakash, 1974). It is the only species included under the subgenus *Cheliones* Thomas, 1919.

Meriones hurrianae (Jerdon)

1867 *Gerbillus hurrianae* Jerdon, Mamm. *India*, 186 (*Hissar, Haryana*).

1919 *Cheliones hurrianae collinus* Thomas, *J. Bombay nat. Hist. Soc.* 26 : 726 (Kohat, Northwest Frontier Province, 1,000-1,700 ft).

Diagnosis

Fossorial, Diurnal, at times crepuscu'ar. Head and body about 100 mm, tail equal to or usually shorter than head and body, with a black pencil of hair at the tip. The ear is short, less than one tenth of body length. Fore and hind foot with well developed claws. Mammae 8. The hairs are short and harsh, light brownish grey, sometimes reddish brown; underparts dirty white to pale yellow. Feet whitish or light brown. Tail as dorsum, a black streak throughout on dorsal side (Ellerman, 1961).

Geographical Distribution

The species is considered to be Irano-Rajasthani in distribution (Prakash, 1974). It is spread from Iran, Afghanistan, Pakistan to the Indian desert (northern Gujarat, western and north-eastern Rajasthan, Haryana and parts of Punjab and Delhi Union Territory).

When alarmed, the desert gerbil 'pops' out of its burrow (above) and gradually leaves it (below)

POPULATION ECOLOGY

On the basis of extensive trapping, attempts have been made to discuss the distribution of the Indian desert gerbil, *Meriones hurrianae* (Jerodn), in Rajasthan desert with reference to various habitat and vegetation types, its relative abundance and its interactions with other rodents. It has been observed that the merion gerbil occurs in a variety of habitats and vegetation types, and is the most abundant rodent of this desert.

The Indian desert gerbil, *Meriones hurrianae* (Jerdon) was collected at one locality in each of the eleven administrative districts of the Rajasthan desert. At each locality trapping was carried out in four habitats, namely, sandy, rocky, gravel plains and ruderal (village complex). In each habitat, two trap lines, containing 30 snap traps in each line at an interval of 10 metres were fixed in a homogenous vegetational community. The two trap lines were 15 metres apart from each other and were run for 72 hours. Snap traps were baited with peanut butter. The frequency of *M. hurrianae* is expressed as the percentage of total number of rodents collected in a habitat and in a locality. Observations on their ecological distribution were also made in the field.

Ecological Distribution

Among the Indian desert gerbil, *Meriones hurrianae* (Jerdon), collected during the survey, 60 per cent were from sandy habitat, 17 per cent from gravel plains, and 23 per cent from the ruderal habitat. No merion gerbil occurred in the rocky habitat. This analysis suggests that the rodent shows a habitat preference for the sandy environment.

Sandy habitat : In the sandy habitat, *M. hurrianae* inhabits a variety of subhabitats. It mostly occurs on the sandy plains and in the interdunal regions. It does not occur on the undulating mobile sand dunes. On the sandy plains as well, it prefers hummocky landscape, which is formed due to a higher density of bushes like *Capparis decidua, Calligonum polygonoides* and *Zizyphus nummularia*. The drifting sand, blown by the strong desert winds, piles around the bushes, giving a hummocky look to the topography. The desert gerbil concentrates its burrows over the hummocks and around it. This type of denning behaviour puts gerbils in an advantageous position, especially in the summer season since due to the presence of extensive root system of the bushes, a higher humidity is maintained in the soil surrounding it, and in their burrows also thus enabling them to withstand the desert temperature comfortably This micro-climate, higher relative humidity and low temperature (Prakash *et al.*, 1965) in the burrows also assist them in maintaining a balanced state of homoestasis.

During the rainy season, the sand dunes are temporarily stabilised and the rodents move to these dunes from the interdunal regions, mainly for foraging since a wide variety of vegetation sprouts on them. At Bikaner, it has been observed that the dunes were completely colonised by the desert gerbils and the spacing in between their burrow openings was even less than half a metre. Excavation of their burrows revealed that, on the temporarily fixed dunes, they do not dig extensive burrow systems but thrive in straight tunnels from a metre to three metres long. These rainy-season-tunnels do not penetrate deep into the soil and are only 5 to 10 cm deep.

In the Shri Ganganagar district, the landscape of most parts of this district has changed from undulating sandy plains to flat, irrigated crop fields during the last 40 years, after the advent of the Ganga Canal. The desert gerbils were as prolific in this district in the pre-canal period, as they are now in any other sandy plain of the Rajasthan desert (Prakash, 1958). The numbers of the desert gerbil have now been drastically reduced indirectly due to the influence of the present day land use pattern. Now *M. hurrianae* occurs near crop fields on uplands where patches of sandy soil are distinct. Througout the crop fields, where the soil is clayey and consolidated, desert gerbils are not found and they are replaced by *Nesokia indica, Tatera indica indica* and *Rattus meltada pallidior*. Taber *et al.* (1967) have also observed that the desert gerbil was once much more commonly distributed through the Lyallpur region in Pakistan. Land levelling for irrigation destroyed the interpersion of dry mounds for burrowing and moist depressions for feeding. Consequently, their numbers have also reduced in Lyallpur over the past century due to the introduction of irrigation.

At certain localities in the desert, the drifting of the sand dunes is checked by hillocks and a huge amount of sand is deposited at the foot of the hill (Barmer, Jodhpur, Jaisalmer and Jhunjhunu districts). At times, such deposits reach 250 to 350 metres above the hillocks. When the sand accumulation is fresh, unstabilised, and is composed of loose soil *Gerbillus gleadowi* migrate to it but as gradually the soil stabilises, *G. gleadowi* are more or less replaced by *M. hurrianae*.

Included in the sandy habitat, we find the desert gerbils in the salt plains near Sambhar Lake, Pachbhadra and Didwana regions. Their burrows are found even in the salt pits, indicating that they can tolerate a high level of salt in the soil without any apparent effect. The desert gerbils in the Pachbhadra salt region, however, look paler than those found in other localities and the hairy tuft at the tip of their tail is brownish-sandy in colour instead of the usual black colour.

Gravelly habitat: There are two chief types of gravel plains found in the Rajasthan desert, one is composed of hard rock pebbles (Jaisalmer-Barmer districts) and the other type is chiefly due to a large number of calcium carbonate concretions which are formed due to upward movement of calcium carbonate, by leaching of soil (Nagaur, northern Jodhpur and Jhunjhunu districts). The desert gerbils do not occur in the first type of gravel plain but commonly occur in the latter, usually in depressions where the grasses and other vegetation grow which provide forage for them.

Ruderal habitat : Our definition of the ruderal habitat includes rather a number of sub-habitats which are influenced by man. Certain villages, and the micro-villages, locally known as 'Dhani', are situated over sand dunes. The Hairy-footed gerbil, *Gerbillus gleadowi,* is the most common rodent around them but *M. hurrianae* occurs in the mud-thorn clad, fences of the *dhani* or a house. These gerbils do not actually enter the houses which are inhabited by *Rattus rattus* and *Mus musculus* but occur in the backyard, cattle sheds, etc. Whether these gerbils thrive on the natural vegetation or depend on man for food is not known precisely.

Prior to pre-monsoon showers, the fields are ploughed for sowing the *kharif* crops. Due to ploughing activity, burrows of desert gerbils are destroyed and they migrate to the fringes of the fields where they re-establish themselves in shallow burrows. Soon after the crops are harvested, two types of their distributional patterns are observed. Some immigrate into the harvested fields and quite a large number colonise the small patches where the crop is stacked and the places where crop grains are being threshed from ears. I have seen as many as 40 desert gerbils in an area of 15 sq metres, foraging on the harvested crops. They also inflict severe damage to standing crops by feeding upon entire plants in early stages of growth and later by cutting the plant and then feeding upon the ripe seeds, both in *kharif* and *rabi* crops.

Relative Abundance

While *M. hurrianae* is distributed all over the Rajasthan desert, it is more abundant in the sandy habitat at Jodhpur, Barmer, Nagaur, Churu, Jhunjhunu and Sikar districts (Prakash, 1972). Their relative abundance, the frequency of *M. hurrianae* being calculated as per cent of total number of rodents collected in the trap lines in 72 hours has been analysed The relative abundance of the desert gerbil appears to be associated with the soil types. In the western districts (Jaisalmer, Bikaner and part of Barmer), the topography is dominated by drifting sand dunes and a lower number of desert gerbils are recorded there. In the northern district of Shri Ganganagar, their frequency is low due to the altered land use pattern due to irrigation cropping. In the south-eastern districts of Pali and northern Sirohi, the soil is too clayey and hence their numbers are low. In one of our earlier communcations (Prakash *et al.*, 1971c), we had stated, on the basis of quantitative data, that *M. hurrianae* numbers and the clay per cent in soil are inversely proportional. But in the central and south-eastern districts the soil is 'Red-desertic' type (Roy and Sen, 1968) and considering their abundance in this region it appears that this soil type is most suitable for them.

Table 2. Per cent basal cover in different vegetation communities and relative abundance of *M. hurrianae* in sandy habitat (Prakash, !972)

Chief vegetation Community	% Basal cover of vegetation	Per cent frequency of *M. hurrianae*
Tephrosia purpurea—Aerva pseudo-tomentosa—Aristida spp.	0.1	53.3
Eleusine compressa—Cyperus arenarius—Calligonum polygonoides	3.2	27.2
Lasiurus sindicus—Cenchrus biflorus—Blepheris sindicum	6.9	25.0
Cyperus arenarius—Aristida spp.—*Crotalaria burhia*	1.0	24.2
Cyperus arenarius—Cenchrus biflorus—Crotalaria burhia	1.3	75 0
Pulicaria wightiana—Sesbania aegyptiaca—Aristida spp.	8.9	35 5
Sporobolus helvolus—Desmostachya bipinnata—Acacia jacquemontii	6.2	54.5
Panicum turgidum—Eleusine compressa—Dactyloctenium scindicum	0.8	75.0
Dichanthium annulatum—Eremopogon faveolatus—Aristida spp.	7.3	present
Cenchrus setigerus—Eleusine compressa—Aristida spp.	1.0	25.0
Zizyphus nummularia—Cenchrus biflorus—Aristida spp.	3 4	28.0
Gram field	—	20.0
Cotton-wheat field	—	57.1
Bajra-chilli field	—	44.5

Relative abundance in relation to vegetation:

Table 2 summarises various vegetational communities in which rodent trapping was done in different habitats, per cent basal cover of vegetation, and the frequency of *M. hurrianae* as per cent of the total number of rodents collected. It is evident that the desert gerbils are found in almost every vegetation type due to their versatility to adapt to a wide variety of food (Prakash, 1962, 1969). It appears from the Table that gerbi's are more common in communities having *Aristida* spp. as a dominant grass (Prakash, 1973). Earlier we had observed (Prakash *et al.*, 1971c) that at six localities in the three bio-climatic zones of the

Rajasthan desert the largest number of this gerbil was associated with the grass *Aristida*. It has also been found that the desert gerbils shift their burrows near the creeper, *Citrullus colocynthis*, when it fruits. A burrow opening can be found near and under every fruit. The fruit is scooped and seeds eaten right from the burrow, without exposing the rodent to climatic and predatory hazards. *M. hurrianae* shuns localities where an abundance of grasses like *Cenchrus biflorus* and *Erianthus munja* grow. The ripe inflorescence of *C. biflorus* is very spiny, which sticks to their body and makes life difficult for the gerbils (Prakash, 1964a). In the 100 mm rainfall region in the extreme west of Jaisalmer district, *M. hurrianae* were found to be associated with the perennial bush, *Haloxylon salicornicum*. Association of this rodent with this bush has also been observed in North Africa by Petter (1961).

Relative abundance in relation to basal cover of vegetation: It is evident that basal cover of the vegetation does not influence the relative numbers of the desert gerbils (Table 1). Seventy-five per cent of the rodents trapped were *M. hurrianae* where the basal cover was only 1.3 and 0.8 per cent respectively, whereas in vegetational communities where the basal cover was high, 7.3, 3.4 and 3.2 per cent, the relative abundance of desert gerbils was not more than 27.2 per cent (Table 1). But in the *Sporobolus-Desmostachya-Acacia* community, where the basal cover was comparatively high (6.2 per cent), the frequency of merion gerbils was also high (54.5 per cent). These findings indicate that the basal cover of vegetation and the frequency of desert gerbils do not have any definite and apparent relationship.

Rodent Associations

In the western districts of the desert. *M. hurrianae* is associated with the Hairy-footed gerbil, *Gerbillus gleadowi* and Wagner's gerbil, *G. nanus indus* (Table 3). In some of the districts, *Rattus gleadowi* and *Mus platythrix sadhu* are also found along with *M. hurrianae*. In the south-eastern districts which receive comparatively more rainfall, *Rattus meltada pallidior* occurs with them along with *Tatera i. indica*. In the gravel plains it lives in association of *T. i. indica* and in the ruderal habitat along with *R. m. pallidior*. More extensive work, which is being taken up, will probably throw some light on the intricate interactions between the various rodent species which inhabit the same habitat.

Population Structure

Live desert gerbils, *Meriones hurrianae* (Jerdon), were collected from the field for our toxicologial work during 1963-64 and 1966-67. Records were maintained with respect to their body weights, sex and age. During both the periods the site of collection was the same and, therefore, an attempt has been made here to deal with the body weight, sex ratio and age structure found in the desert gerbil population during the two years. Interesting facts about the population structure have come to light.

During 1963-64, merion gerbils were collected by flooding their burrows with water. No sooner the rodents rushed out, they were scooped with butterfly nets and transferred to cages. During 1966-67,

Table 3. Rodent associates of *M. hurrianae* in the Rajasthan desert (Prakash, 1975a)

Rajasthan desert districts	Rodent associations (based on frequency of trapping. first species being the most abundant
	Sandy Habitat
Barmer	*Meriones hurrianae—Gerbillus gleadowi*
Bikaner	*M. hurrianae—G. gleadowi—Gerbillus nanus indus—Rattus gleadowi*
Jaisalmer	*G. gleadowi—G. n. indus—M. hurrianae*
Jodhpur	*M. hurrianae—Rattus meltada pallidior—Tatera indica indica*
Jhunjhunu and Sikar	*G. gleadowi—T. i. indica—M. hurrianae*
Churu	*M. hurrianae—G. gleadowi*
Nagaur	*M. hurrianae—T. i. indica—R. m. pallidior*
Pali	*M. hurrianae—T. i. indica*
Jalore	*M. hurrianae—G. gleadowi*
Sirohi	*M. hurrianae—R. m. pallidior—T. i. indica*
	Gravelly Habitat
Rajasthan desert	*M. hurrianae—T. i. indica*
	Ruderal Habitat
Rajasthan desert	*T. i. indica—R. m. pallidior—M. hurrianae*

however, they were collected by trapping in Sherman live traps. During both the years they were collected from natural grasslands comprising mainly of *Cenchrus biflorus, C. setigerus, C. ciliaris, Aristida adscensionis* and *Cyperus rotundus*. The site of collection was the Central Research Farm of the Institute situated at Jodhpur. Body weights of gerbils were taken on a triple-beam scale (accuracy 1/10 g) soon after their capture. They were sexed. With respect to age, the gerbils were classed into two groups: those weighing below 40 g were regarded as subadults and the rest as adults. This categorisation was made following Ghosh (1968) who observed that sexual maturity is attained by them around the body weight of 40 gm.

Body Weight of Adult Gerbils

Body weight trend through the year: The mean monthly body weights of adult desert gerbils fluctuate around 60 g during 1963-64 and around 70 g during 1966-67 (Table 4a). Body weights tend to decline after winter and reach a low

Table 4a. Mean monthly body weights of adult desert gerbils during 1963–64 and 1966–67 with standard errors (Prakash, 1971a)

Month	1963–64		1966–67		't' between					
	Male 1	Female 2	Male 3	Female 4	1 & 2	1 & 3	1 & 4	2 & 3	2 & 4	3 & 4
January	79.15 ± 2.14	59.57 ± 3.43	71.04 ± 3.98	66.14 ± 3.16	4.51*	1.81	3.42*	1.80	1.40	0.87
February	68.46 ± 6.75	56.24 ± 2.97	75.61 ± 4.97	62.48 ± 2.31	1.67	1.86	0.84	3.38*	1.68	2.41*
March	63.90 ± 3.83	52.41 ± 1.98	70.67 ± 3.01	68.50 ± 2.54	2.67	0.43	1.00	5.12*	5.05*	0.54
April	54.50 ± 8.94	53.12 ± 2.64	—	—	0.15	—	—	—	—	—
May	59.00 ± 6.40	47.5	—	—	—	—	—	—	—	—
June	75.33 ± 9.47	72.66 ± 11.7	—	—	0.17	—	—	—	—	—
July	46.10 ± 1.00	50.75 ± 2.71	65.80 ± 2.29	66.81 ± 2.10	0.45	1.94	1.93	4.13	4.72*	0.26
August	62.54 ± 1.58	51.71 ± 1.41	73.63 ± 1.75	63.76 ± 2.05	4.53*	4.33*	0.08	9.87*	5.04*	3.71*
September	69.11 ± 2.25	57.34 ± 1.77	79.18 ± 5.41	65.99 ± 5.36	4.17*	1.74	0.54	3.89*	1.54	1.74
October	—	—	74.63 ± 3.35	78.49 ± 2.37	—	—	—	—	—	0.83
December	65.51 ± 3.27	64.05 ± 2.95	74.41 ± 4.28	65.67 ± 3.14	0.33	1.65	0.03	2.00*	0.38	1.65

*Significant at 5 per cent level.

in summer, thereafter they increase. A steep peak is, however, observed in June, the hottest month during which climatic conditions are very hostile and there is severe paucity of food (Prakash, 1971a). Such a peak has also been observed by my co-worker in the Indian gerbil, *Tatera indica indica,* which were collected from Bikaner during 1968 (Jain, 1970). It is difficult to assign any definite reason for this sudden increase in the body weight of adult merion gerbils but in both the species (Prakash, 1962; Jain, 1970) a peak is also shown in the reproductive activity in both the sexes. Whether the peaks in reproductive activity and body weights are independent characteristics or whether there is a cause and effect relationship between the two can be ascertained only when further work is done. On the whole, the trend of variations in mean monthly body weights of adult gerbils appear to be parallel to the availability of food in the desert tract. Minimum food is available in natural condition during summer months when all the vegetation dries and, therefore, the body weights are also minimum during these months. During the monsoon and post-monsoon seasons when vegetation is green, the rodents gain body weight. During winter when the vegetation starts drying, the gerbils also start losing body weight and it continues till summer.

Differences between sexes: Male desert gerbils are found to be heavier than the females in all the months except in October, 1966 (Prakash, 1971a). This difference, however, reached the level of significance (Table 3), only in January, August and September during 1963-64 and in February and August during 1966-67.

Differences between years: The mean monthly body weights of male desert gerbils collected during 1966-67 were higher as compared to those of male gerbils collected during 1963-64 except in January (1963-64) but the difference was statistically significant only during August. Similar was the trend in the body weights of adult female gerbils between the two periods, significant differences (Table 3) being observed in the months of March, July and August. It is noteworthy, that significant differences in the body weight of both the sexes were observed during monsoon season, body weights being heavier in 1966-67 during which year the total precipitation (280 mm) was more as compared to that in 1963-64 (184 mm). It may indicate that a greater availability of green food directly influences the health of the rodents resulting in an increased prevalence of pregnancy and in an increase in the litter size (Prakash, 1964b).

Distribution of body weights in the samples: In Table 4b the body weights of the desert gerbil are classed at 20 g intervals. The two classes, up to 20 g and 20.1-40 g represent subadult gerbils. It is observed that these two classes are not distributed uniformly in the population during 1963-64 whereas during 1966-67, their distribution is more or less regular. Noteworthy is the poor representation of these classes during monsoon which is reported (Prakash, 1964b) to be the period of their peak littering activity. The weight classes 40.1-60.0 g and 60.1 to 80.0 g are distributed almost throughout the year in both the sexes during 1963-64, and these two and the 80.1 to 100 g class are distributed similarly during 1966-67. It is interesting to

Table 4b. Monthly distribution of weight classes of male and female desert gerbils during 1963-64 and 1966-67 expressed as per cent of monthly collection (Prakash, 1971a)

Wt. class	1963-64 Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Dec.	1966-67 Jan.	Feb.	Mar.	July	Aug.	Sept.	Oct.	Dec.
Upto 20 gm.	—	5.2	7.1	25	12.5	—	—	—	—	—	3.7	7.7	2.3	—	—	—	2.5	—
20.1 — 40.0	—	52.6	42.8	—	37.5	—	—	2.5	—	—	33.9	23.0	11.9	2.8	—	17.3	15.0	7.9
40.1 — 60.0	100	15.8	50.0	50	25.0	33.3	66 6	42.5	24.0	46.1	20.7	19.2	26.1	38.2	12 0	13.0	27.5	28.9
60.1 — 80.0	100	15.8	—	25	25.0	33.3	33 3	52.5	52.0	46.1	20.7	15.3	33.3	38.2	62.0	34.6	20.0	26.3
80.1 — 100.0	—	10.4	—	—	—	33.3	—	2.5	24.0	7.7	18.8	27.0	21.4	20.6	22.0	21.7	30.0	31.5
100.1 — 120.0	—	—	—	—	—	—	—	—	—	—	—	7.7	4.6	—	4.0	8.7	5.0	2.6
120.1 & above	—	—	—	—	—	—	—	—	—	—	1.8	—	—	—	—	4.3	—	2.6
Upto 20 gm.	41.3	7.7	16.3	—	—	—	—	—	—	22.2	—	9.1	11.7	—	—	—	1.8	—
20.1 — 40.0	27.5	46.0	32.6	45.4	87.5	16.6	—	8.6	—	16.1	23.7	22.7	23.4	—	—	5.5	12.9	20.4
40.1 — 60.0	17.2	27.0	38.1	45.4	12.5	16.6	100	80.0	66.6	22.2	37.2	30.0	17.6	32.3	46.4	50.0	7.3	36.7
60.1 — 80.0	13.7	19.2	12.7	9.1	—	33.2	—	11.4	33.3	29.0	22.1	28.7	27.4	58.0	42.8	27.7	38.8	22.4
80.1 — 100.0	—	—	—	—	—	33.2	—	—	—	9.5	13.5	7.5	19.6	6.4	10.7	11.1	33.3	16.3
100.1 — 120.0	—	—	—	—	—	—	—	—	—	—	1.6	1.3	—	3.2	—	—	5.5	4.1
120.1 & above	—	—	—	—	—	—	—	—	—	—	1.6	—	—	—	—	5.5	—	—

note that the 80.1-100 g class is very poorly represented during 1963-64. Moreover, the 100.1-120 gm and 120.1-140 g classes are completely absent in both the sexes during 1963-64 whereas they are represented during 1966-67. These observations indicate that during the earlier year the older (heavier) gerbils were not present in the population although the chances of their collection, if they were present, were much more as they were being collected by flooding their tunnels and chances of their escape were minimal. This may be related to the poor feeding conditions available to desert gerbils during the previous year when the rainfall was poor (184 mm) as compared to 1966-67 (280 mm) (Prakash, 1971a).

Body Size

The merion gerbils were snap-trapped at Jodhpur (26°18'N-73°01E) and Maulasar (27°24N-74°35E) in the Rajasthan desert. A comparison of various body and cranial measurements* has been made with (Prakash & Kumari, 1978) those of the sample from (Umarkot, 25°N-70°E) Sind (Pakistan) as per the data presented by Ellerman (1961).

Table 5 and Table 6 present the variations and statistical analyses of standard body measurements and cranial measurements of male and female *M. hurrianae* collected from the two localities in Rajasthan desert and those from Sind (Thal desert).

Difference between sex: The male *M. hurrianae* are longer in respect of all the standard body measurements than female from both the locations in the Rajasthan desert (Table 5); except that the ear of female population in Maulasar is straightly larger than that of its counter part. However, these inter-sex differences are not statistically significant. Surprisingly, however, the females of Sind are fairly larger than males, significant differences being in respect of hind foot ($P<0.05$) and ear ($P<0.05$).

In the Jodhpur population of *M. hurrianae*, skull of male animal is larger in almost all the measurements but significant differences exist only in respect of condylobasal ($P<0.05$) and occipitonasal length ($P<0.05$), length of tympanic bulla ($P<0.001$), palatal length ($P<0.05$). In the Maulasar population, skull of male gerbils are larger in some respects (Table 6) but the measurement of rostral, tympanic bullae the upper and lower molar regions of females are larger. The significant difference pertains only to the breadth of tympanic bulla ($P<0.05$), that of male being wider.

Difference between the three populations: The interesting feature among the three populations of *M. hurrianae* is that the head and body length of Sind population is smaller than that of Jodhpur and Maulasar rodents but rest of the standard body measurements are longer than that in the latter two populations, except hind foot of males of Sind and Maulasar (Table 5). The male Desert gerbils of Jodhpur are significantly larger ($P<0.05$) than those of Sind in their head and body measurements. Significant level of difference in tail length is seen in between females of Sind and Jodhpur ($P<0.01$) and Sind and Maulasar ($P<0.001$). At

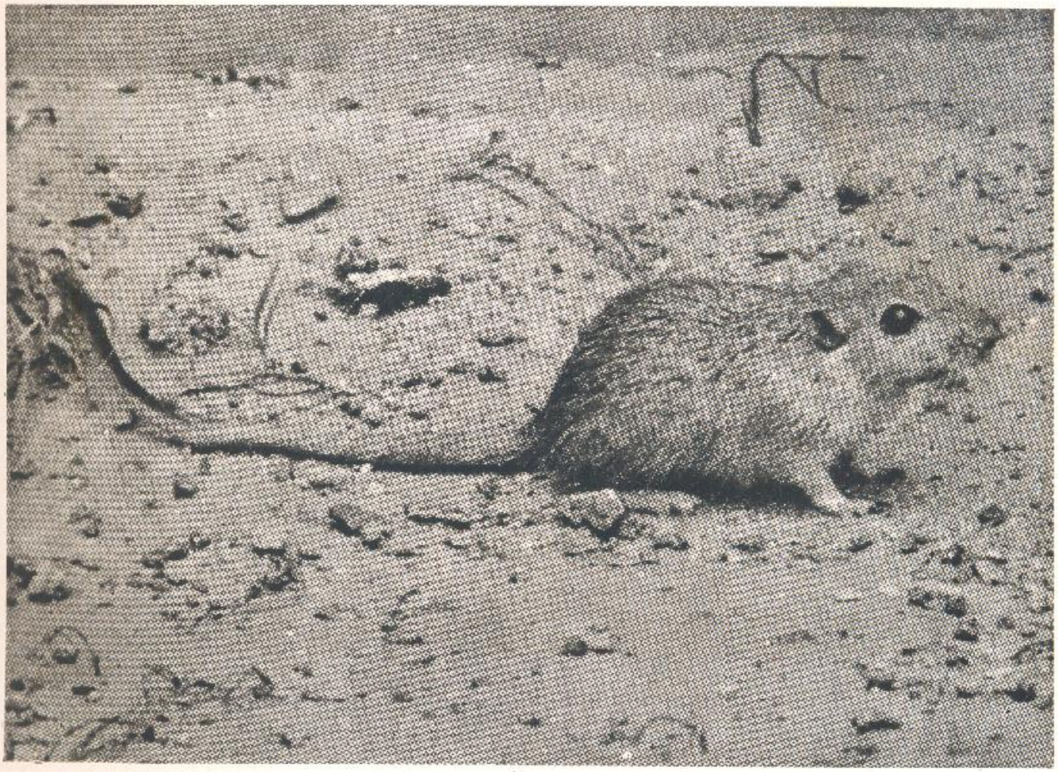
*All measurements are after Jain et al., 1975 and Rana et al., 1970, 1975.

Table 5. Variation in the mean values (± SE) of external body parts (mm) of Meriones hurrianae from three populations (Prakash and Kumari, 1978)

Body parts	Sind population		Jodhpur population		Maulasar population	
	Males (N=14)	Females (N=16)	Males (N=10)	Females (N=10)	Males (N=12)	Females (N=15)
Head and body	120.84 ± 2.33	122.00 ± 3.03	128.37 ± 2.07	124.75 ± 2.60	126.80 ± 3.21	125.26 ± 2.71
Tail	116.00 ± 6.03	125.53 ± 5.00	114.87 ± 2.56	109.00 ± 3.25	115.12 ± 2.08	109.15 ± 2.14
Hind foot	28.00 ± 0.89	29.87 ± 0.56	27.12 ± 0.37	26.12 ± 0.49	28.50 ± 0.36	27.26 ± 0.78
Ear	10.07 ± 0.30	10.93 ± 0.23	8.75 ± 0.24	8.50 ± 0.32	8.05 ± 0.08	8.26 ± 1.40

Table 6. Variation in the mean values (±SE) in the cranial characters (mm) of Meriones hurrianae from three populations (Prakash and Kumari, 1978)

Cranial characters	Sind population		Jodhpur population		Maulasar population	
	Males	Females	Males	Females	Males	Females
Occipitopremaxillar length	—	—	30.35 ± 0.36	29.50 ± 0.33	29.45 ± 0.43	29.53 ± 0.24
Condylobasal length	—	—	32.00 ± 0.41	30.70 ± 0.31	30.95 ± 0.42	31.20 ± 0.24
Occipitonasal length	33.74 ± 0.24	33.33 ± 0.46	34.27 ± 0.46	33.00 ± 0.36	33.73 ± 0.45	33.70 ± 0.43
Zygomatic width	—	—	19.60 ± 0.39	19.16 ± 0.45	19.10 ± 0.48	19.73 ± 0.23
Inter orbital width	—	—	10.50 ± 0.40	9.90 ± 0.44	10.70 ± 0.30	11.10 ± 0.35
Cranial width	—	—	16.15 ± 1.69	15.85 ± 0.18	15.90 ± 0.15	15.86 ± 0.12
Occipital breadth	—	—	17.18 ± 0.25	17.10 ± 0.26	17.40 ± 0.23	17.53 ± 0.12
Mean depth of cciput	—	—	8.60 ± 0.73	9.05 ± 0.17	9.44 ± 0.18	9.16 ± 0.14
Post molar length	—	—	15.20 ± 0.23	14.90 ± 0.03	14.87 ± 0.20	14.63 ± 0.19
Auditory length	—	—	11.00 ± 0.09	11.80 ± 0.16	11.90 ± 0.25	11.69 ± 0.14
Length of tympanic bulla	9.94 ± 0.92	9.85 ± 0.17	10.25 ± 0.22	9.85 ± 0.16	9.70 ± 0.73	9.83 ± 0.18
Breadth of tympanic bulla	—	—	7.10 ± 0.14	7.05 ± 0.11	7.30 ± 0.14	6.93 ± 0.11
Length of nasals	—	—	12.46 ± 1.33	12.15 ± 0.27	12.05 ± 0.26	12.20 ± 0.25
Combined width of nasals	—	—	3.38 ± 0.15	3.45 ± 0.13	3.63 ± 0.09	3.58 ± 0.11
Palatal length	16.27 ± 1.63	17.25 ± 0.30	16.02 ± 0.26	14.95 ± 0.34	15.15 ± 0.24	15.13 ± 0.20
Length of diastema	—	—	8.08 ± 0.20	8.26 ± 0.19	8.31 ± 0.16	7.60. ± 0.78
Combined width of palatine foramina	5.45 ± 0.22	5.41 ± 0.13	6.26 ± 0.16	5.85 ± 0.23	6.10 ± 0.17	6.33 ± 0.12
Combined width of palatine foramina	—	—	2.99 ± 0.27	2.82 ± 0.10	3.10 ± 0.06	3.00 ± 0.06
Length of upper molars	5.04 ± 0.09	5.01 ± 0.11	5.62 ± 0.11	5.20 ± 0.10	5.18 ± 0.18	5.25 ± 0.11
Length of lower molars	—	—	5.50 ± 0.14	5.05 ± 0.08	5.30 ± 0.13	5.36 ± 0.10
Mandibular length	—	—	15.95 ± 0.51	15.45 ± 0.30	15.75 ± 0.34	15.86 ± 0.19



The Indian desert gerbil (above) makes about 10 to 15 burrow openings (below).

all localities the tail length is smaller than head and body length except in the female rodents of Sind where it is 102.89 per cent of head and body length. The hind foot of females of Sind is significantly longer than those of females of Jodhpur ($P<0.001$) and Maulasar ($P<0.001$); and that of males of Maulasar as compared to males of Jodhpur ($P<0.01$). Hind foot measurement of both sexes in Sind population is significantly larger than that of Jodhpur population (male ($P<0.05$, female $P<0.001$) and Maulasar (male $P<0.001$; female $P<0.05$). Likewise, the ear length of male gerbils of Jodhpur is significantly longer than that of Maulasar gerbils ($P<0.001$).

No major difference in the skull characteristics of three populations is observed. However, the palatal length of Sind rodents is longer than those of the two other populations, significantly with Jodhpur (male and female $P<0.001$), and Maulasar (female $P<0.001$). The length of anterior palatine foramina in Sind skulls was smaller than that of the gerbils of Jodhpur and Maulasar, the level of significance in difference ranging from 0.05 to 0.001. Between the Jodhpur and Maulasar populations, the skull of Maulasar females were longer in respect of occipotonasal length ($P<0.05$), Zygomatic width ($P<0.05$), interorbital width ($P<0.001$), length of anterior palatine foramina ($P<0.001$) and length of lower molars ($P<0.01$). Significant differences also exist in the measurements of male rodents in respect of length of diastema ($P<0.001$) and combined width of anterior palatine foramina ($P<0.05$), Maulasar species being bigger; and length of longer molars ($P<0.05$) and Maulasar length ($P<0.001$), the Jodhpur animals being of longer size (Prakash and Kumari, 1978).

The comparison of various standard body parts of *M. hurrianae* from the three bioclimatic zones of the Indian desert, indicates that the body size of the rodents is smallest in the region of low rainfall and high aridity index (water deficiency as a percentage of water need) but they possess longest tail, hind foot and ear (Table 7). Similar finding was also observed for the species of *Gerbillus* inhabiting this region (Rana *et al.*, 1975). The present observations further confirm our earlier interpretation that the body length decreases with the increasing aridity and the tail and ear length increases accordingly. The functional advantages of

Table 7. Relationship between body size (average of both the sexes), aridity indices, and annual average rainfall (mm) in *M. hurrianae* from three populations (Prakash & Kumari 1978)

Character	Sind	Jodhpur	Maulasar
Head and body (mm)	12.12	126.6	126.0
Tail (mm)	120.8	111.9	112.1
Hind foot (mm)	28.9	26.6	27.9
Ear (mm)	10.5	8.6	8.1
Aridity index	—94	—80	—73
Annual rainfall (mm)	91.4	366	430.5

these xeric adaptations are that the rodents of the same species become more saltatorial in extreme desert (Sind) as compared to semiarid environment, as a result of which the hind foot elongates to withstand the impact of the jump and also the tail to maintain the balance while the rodent is jumping.

The study also points our that the entire population of *M. hurrianae*, spread from Sind to eastern parts of the Great Indian Desert is more or less homogenous in morphological characteristics. The homogeneity of the species suggests that its immigration to the Indian desert from the arid zone of middle-east occurred fairly early in the geological sequence and that the Indian desert is not a man-made or a young desert as hitherto claimed by the archaeologist and historians (Krishnan, 1952) that the onset of aridity in the Indian sub-continent had started much earlier. This study further strengthens the views expressed earlier (Prakash, 1974) in the context of zoogeography of mammals of the Great Indian Desert.

Age Structure

Adult-subadult ratio : The proportion of sub-adult gerbils in the population of desert gerbils in 1963-64 was significantly higher than (d=4.03) those in the population of 1966-67 (Table 8). It is rather difficult to visualise the possible reasons for this significant difference as it is expected that the number of subadult gerbils should be more during 1966-67 when there was a comparatively larger population of heavier animals and during which year the feeding conditions were also superior to 1963-64. This paradoxical situation may perhaps be explained on the basis of the difference in the modes of collection of the animals during the two years. During 1963-64, they were collected by flooding their warrens with water and, therefore, even those young ones which had not weaned and which did not usually venture out of burrows were also forced to move out and collected. Hence a higher representation of younger animals (20 g and below) was found in the population of 1963-64 as

Table 8. Adult and Subadult desert gerbils in the 1963-64 and 1966 67 populations (Prakash, 1971a)

	Jan.–June		July–December		d = normal deviate between subadult population in the two halves of year
	Adult	Subadult	Adult	Subadult	
			Male		
1963–64	36	17	83	1	4.76*
1966–67	87	34	170	15	4.44**
			Female		
1963–64	67	79	77	15	6.75**
1966–67	123	53	161	19	4.78*

*Significant at 5 per cent level of probability.
**Significant at 1 per cent level of probability.

compared to that 1966-67 (34 as against 19) (Prakash, 1971a).

Table 8 also indicates that the number of male subadult gerbils collected during both the years was significantly less as compared to female subadult gerbils (1963-64—$x^2(1) = 28.8$, $P<0.01$; 1966-67—$x^2(1) = 16.93$, $P<0.01$).

It is further clear from Table 8 that the numbers of subadult male and female desert gerbils, during both the years, collected during the first half of the year (January to June) is significantly higher than those collected during the second half of the year (July to December). This would suggest that the rate of reproduction in desert gerbils is higher during the first half of the year as compared to that in the latter half.

Sex Ratio

Table 9 shows the monthly and yearly sex ratios observed in the two samples. For purposes of comparison, the sex ratios observed in the collection made earlier (Prakash, 1962) have also been included. It can be seen from the Table that the numbers of male in the 1953-55 collection was slightly more than 50 per cent but in the latter collections, it never reached the 50 per cent level. The yearly ratios in the 1953-55 and 1966-67 samples do not depart from the hypothetical 50:50 male-female ratio but during 1963-64 the male desert gerbils are significantly ($x^2(1)=27.4$, $P<0.01$) less in number in the yearly sample, being only 36.5 per cent of the total. During both the years the numbers of male subadult gerbils was also significantly less than that of female subadult gerbils in respective populations (1963-64, $P<0.01$; 1966-67, $P<0.05$). This poor representation of subadult male gerbils could possibly be due to three reasons: the number of males was very low among the new born, trap reaction was different with respect to male and female subadult gerbils, and mortality of male subadults was more as compared to that of female subadults.

It is very unlikely that the number of males was lower at the newborn stage. This view is supported by the observed sex ratio of newborn in the northern palm squirrel, *Funambulus pennanti* Wroughton and Indian gerbil, *Tatera indica indica* Hardwicke which inhabit the same locality. The male to female ratio of these species have been reported as 1.1:1 (Purohit *et al.*, 1966) and 1.1:1 (Jain, 1970) respectively. In young desert gerbil also. it is quite likely that both the sexes would be represented in equal numbers.

If trappability of male and female young was different, it may be the reason of poor representation of male subadults in the population of 1966-67, but during 1963-64 the desert gerbils were collected by flooding their warrens and, therefore, their trap response cannot be a factor responsibile for the low number of male subadults.

It is quite likely that mortality rate in male subadults is much more than that in females. A low number of male subadults have also been observed in the palm squirrel (Purohit *et al.*, 1966), and in the Indian gerbil (Jain, 1970). Since the male desert gerbil increases its home range when it attains sexual maturity and during the breeding season (Fitzwater and Prakash, 1969), the maturing male gerbils have to, therefore, encounter hostile behaviour from other territorial adult males and it can be expected that in the

Table 9. Sex ratio in the desert gerbil during 1953–55, 1963–64 and 1966–67 (Prakash, 1971a)

	1953–55			1963–64									1966–67								
	Adult and Subadult			Adult			Subadult			Total			Adult			Subadult			Total		
January	22	26	45.8	2	9	18.1	0	20	0	2	29	6.4	33	45	42.3	20	14	58 8	53	59	47.5
February	8	9	47.0	8	12	40.0	11	14	44.0	19	26	42.2	18	45	28.5	8	21	27.5	26	66	28.2
March	88	11	42.1	13	28	31.6	1	27	3.5	14	55	20.2	36	33	52.1	6	18	25 0	42	51	45.1
April	5	4	55.5	3	12	20.0	1	10	9.1	4	22	15.3	—	—	—	—	—	—	—	—	—
May	4	4	50.0	4	1	80.0	4	7	36.3	8	8	50.0	—	—	—	—	—	—	—	—	—
June	2	2	50.0	6	5	54.5	0	1	0	6	6	50.0	—	—	—	—	—	—	—	—	—
July	5	6	45.4	6	2	75.0	—	—	—	6	2	75.0	33	31	51.5	1	0	100.0	34	31	52.3
August	10	7	58 8	39	32	54.9	1	3	25.0	40	35	53.3	50	28	64.1	0	0	0	50	28	64.1
September	13	12	52.0	25	24	50.2	—	—	—	25	24	50.2	19	17	52.7	4	1	80,0	23	18	56.1
October	9	4	69.2	—	—	—	—	—	—	—	—	—	33	46	41.7	7	8	46 6	40	54	42.5
December	8	8	50.0	13	19	40.6	0	12	0	13	31	29.5	35	39	47.3	3	10	23.1	38	49	43.6
Total	94	93	50 2	119	114	45 2	18	94	16.1	137	238	36.5	257	284	47.5	49	72	40.5	306	356	46.2

process a substantial number of young perish. In addition to the mortality caused by social interactions, some subadult male desert gerbils may also die as they are less adaptable to xeric conditions as compared to female gerbils. A higher rate of mortality may be the possible reason of the poorer representation of male subadult gerbils in the populations as compared to that of female subadult gerbils.

Seasonal Population Fluctuations

There is no literature on the fluctuations of desert gerbil population except for some stray remarks by naturalists (Adams, 1899; Blanford, 1888-91; Jerdon, 1867). To fill up this lacuna in our knowledge of the desert gerbils, attempts were made by us to undertake a population study on this species by the conventional capture-recapture technique, but the inherent trap-shyness of these rodents led us to abandon this technique. The present study was, therefore, done employing an indirect census method which only required the counting of freshly-opened burrow openings. Although this technique may have certain limitations, yet, for purposes of comparison between localities and between seasons, it has sufficient validity.

Methods

Number of desert gerbils: It was observed that soon after venturing out of their burrows in the morning, the desert gerbils feed continuously for 30-45 minutes and do not indulge in burrow digging. This habit of the gerbils was utilized in formulating the census method which involved plugging of all the burrow openings in the evening after cessation of all surface activity followed by counting of all the freshly-opened burrow openings in the next morning within about half an hour of the start of their morning activity. Since during this period a gerbil is not likely to make more than one burrow opening, each fresh burrow opening should represent one gerbil. This was checked in small plots by ocular counting before initiating the study. Plots measuring 90 x 90 m were worked and divided in subplots of 7.5 x 7.5 m. In each subplot all the burrow openings were closed at evening and the freshly opened ones were counted next morning. The plots were situated at Jaisalmer and Chandan (180 mm average annual rainfall); Barmer and Gadra Road (300 mm); and Lachhmangarh and Palsana (450 mm) representing the main rainfall zones of the Rajasthan desert. Census by burrow closing-opening method was carried out in summer (June), monsoon (August), post-monsoon (October), and winter (December) seasons. The trend of the population number being similar the data for both the work sites in each rainfall zone was pooled.

Vegetation: The vegetation was studied by the line intercept method (Cainfield, 1941) in 8 transects at each work site in every seasons.

Soil characteristics: The field density of soil was worked out by the British Standard Test No. 10 C and the per cent clay and permeability of the soil according to Darsy's Law method (SOIL MECHANICS FOR ROAD ENGINEERS, HMSO, London, 1961).

Climate: The climatic data have been taken from Pramanik and Hariharan (1952) and also from the Climatology Section of the Institute.

Table 10. Average annual number of desert gerbil in relation to climatic factors and vegetation (Prakash *et al.*, 1971a)

Rainfall zone	Average annual number of desert gerbil per 90m x 90m plot	Total plant cover %	Grass cover %	Rainfall (mm)	Mean maximum temp. °C	Mean minimum temp. °C	% relative humidity of air 08.00 hrs.
Jaisalmer-Chandan	31	6.66	5.98	178	33.6	18.7	66
Barmer-Gadra Road	458	3.5	1.29	314	33.6	20.2	60
Lachhmangarh-Palsana	247	2.69	1.80	441	32.5	17.5	64

Vegetation Cover

The vegetation in all the three zones comprise chiefly of grasses, the most common species being: *Cenchrus ciliaris, Cenchrus setigerus, Cenchrus biflorus. Lasiurus sindicus, Aristida adscensionis, Eleusine compressa, Perotis hordeiformis, Chloris virgata, Cymbopogon jwarancusa, Digitaria marginata, Brachiaria ramosa* and *Dactyloctenium scindicum.* etc. The other prominent species of plants occurring in these sites are *Zizyphus nummularia, Tephrosia purpurea, Aerva tomentosa, Crotalaria burhia, Capparis aphylla, Calotropis procera, Pulicaria wightiana, Leptadenia pyrotechnica, Calligonum polygonoides, Indigofera* sp. etc. The main tree species are: *Prosopis spicigera, P. juliflora, Acacia* spp., *Azadirachta indica, Salvadora oleoides,* etc. On the basis of frequency and density, the following plant communities were found at the three experimental sites: Barmer and Gadra Road (BG), *Cenchrus-Indigofera-Dactyloctenium-Aristida* community; Jaisalmer and Chandan (JC), *Eleusine-Aristida-Lasiurus* community; Lachhmangarh and Palsana (LP), *Digitaria-Aristida-Cenchrus-Pulicaria* community.

The average annual plant cover at JC, BG and LP tracts was 6.66, 3.0, 2.69 per cent respectively and the grass cover was 1.19, 5.98, 1.80 per cent respectively. Table 10 shows the fluctuations in the total plant as well as grass covers during various seasons. It will be observed that at BG and JC regions the cover was more in summer than in spring which was presumably due to early showers in the month of June.

Soil Characteristics

The field density of soils from LP and JC regions show very little difference (Table 11). These soils are denser than the soil at BG region since the field density of soils in the region is 1.36 g/cm as compared to 1.80 to 1.82 g/cm at the LP and JC regions respectively. The soils of JC regions have the maximum amount of clay whereas the clay content is least in the soils of BG tract. Permeability of the soil for the seepage of water is maximum in the JC region and lowest in the BG tract.

Desert Gerbil Numbers

Average annual number in three rainfall zones: The average annual number of the desert gerbils was maximum per experimental plot in the Barmer-Gadra Road tract and minimum at the Jaisalmer-Chandan tract (Table 10).

Table 11. Characteristics of soils of BG, LP and JC regions (Prakash *et al.*, 1971c)

Localities	Field density (gm/cc)	% clay	Permeability (gm/hr)
Jaisalmer-Chandan	1.80	5.3	0.8081
Barmer-Gadra Rood	1.36	3.1	0.1622
Lachnmangarh-Palsana	1.82	4.5	0.3485

Seasonal fluctuations in gerbil numbers: The gerbil numbers show an annual trend which is identical for the Jaisa'mer-Chandan and Lachhmangarh-Palsana regions (Prakash *et al.*, 1971c). In those two tracts, their number is low in summer, slightly builds up during monsoon and reaches a peak in winter; whereas at Barmer-Gadra Road tract, their number is minimum during summer, somewhat higher in winter, reaches a peak in spring and declines in summer (Tab'e 12). The differences in number between seasons were maximum in the JC region, which a'so has the maximum climatic conditions as compared to the other two tracts.

Average annual number of desert gerbil in relation to climatic factors: It is evident from Table 10 that the variation in the mean maximum and mean minimum temperatures at the three zones is only of the order of 1.6°C to 2.7°C whereas the gerbil number varies from 31 to 458. It, therefore, appears that the number of desert gerbils is not perhaps affected by temperature fluctuations in these three zones, which is expected since their burrows are comparatively cooler than the surrounding soil surface (Prakash *et al.*, 1965). As the rodents develop hyperthermia due to exposure to the sun during their diurnal surface activity, they enter the burrows and the excess body heat is then intermittently unloaded to the coo'er environment (Schmidt-Nielsen, 1964; Fitzwater and Prakash, 1969). It has, however, been observed that in JC tract where the gerbil number was the least per plot, the mean annual relative humidity was the highest and vice versa at BG region. It would appear, therefore, that the population density of gerbils is

Table 12. Seasonal fluctuations in numbers of desert gerbil in relation to climatic factors and vegetation (Prakash, *et al.*, 1971c)

Season	Gerbil No. per 90 m x 90 m	% plant cover	% grass cover
	Jaisalmer-Chandan Region		
Monsoon (August)	12	9.97	9.2
Winter (December)	107	5.4	5.3
Spring (March)	3	4.5	3.95
Summer (June)	5.5	5.9	5.5
	Barmer-Gadra Road Region		
Monsoon	110	42.2	1.30
Winter	560	1.7	0.67
Spring	795	2.2	0.68
Summer	367	3.9	2.57
	Lachhmangarh-Palsana Region		
Monsoon	388	3.4	2.8
Winter	488	3.42	2.5
Spring	91	2.3	1.28
Summer	21	1.62	0.66

inversely related to atmospheric relative humidity. However, the constancy of the humidity conditions prevailing inside the burrows should be of more immediate consequence for population build-up in this species. The number of desert gerbils was found to be minimum in JC tract where the amount of annual precipitation is also the lowest. The next higher rainfall zone (BG), however, shows the maximum number of desert gerbils (Table 10). It, therefore, appears that the amount of precipitation is not an important factor for the density distribution in various zones. Another possibility is that a medium rainfall zone like Barmer-Gadra Road region, is more suitable for their population build up as it is neither too dry nor too wet.

Average annual number of desert gerbils in relation to vegetation: It was observed that the number of gerbils was higher in plots which had *Dactyloctenium scindicum, Aristida adscensionis, Lasiurus sindicus, Perotis indica, Digitaria marginata* and lower in plots having a high frequency of *Cenchrus biflorus* plants The above mentioned grasses are preferred as food by the desert gerbils. Although it also feeds on *C. biflorus* but when the inflorescence ripens the awns become so sharp that they are repulsive to the rodents.

The average annual number of gerbils was minimum in JC tract where the total plant cover as well as the grass cover was the highest. In the two other tracts the higher gerbils numbers were associated with a lower plant as well as grass cover (Prakash *et al.*, 1971c). This would look paradoxical since in areas with the higher plant cover food available should be more and a higher gerbil population should, therefore, be expected. This paradox can be explained on the basis of their burrowing habit. The gerbils cannot easily dig their extensive burrows when they are confronted with the anastomosing, fibrous roots of grasses which form by far the majority of the vegetation of these tracts. Moreover, the extensive root systems make the soils more compact making burrowing more arduous. Our observations in the field also confirm that gerbils are densely distributed in open sandy plains as compared to heavily vegetated patches. Smith (1958) also observed that the dense vegetation is a limiting factor in the establishment of new dog-towns of the prairie dog, *Cynomys ludovicianus*.

Average annual number in relation to edaphic characteristics: A comparison of soil characteristics and the gerbil numbers (Table 10 & 11) reveals that in the tracts where field density, permeability and clay per cent of soil was maximum (C), the gerbil number was minimum, and vice versa (BG), which indicates that the gerbil numbers tend to be low where the soil is denser, has a higher permeability for seepage of water and is clayey in nature. Denser soils are usually more clayey and, therefore, burrowing should be difficult. It may, therefore, be one of the important factors affecting the relative abundance of desert gerbils in various localities. Another reason for their shunning the compact clayey soils could be that more permeable soil will allow more seepage of rain water which would retain it for greater durations as compared to the looser soils which would probably disturb the micro-climatic balance inside the burrows.

Seasonal fluctuations in gerbil numbers with respect to ecological factors: The desert gerbi's stay during the periods of unfavourable climate inside the burrows which provide them with a comfortable and homogeneous micro-climate (Prakash *et al.*, 1965). Moreover, the desert gerbils are by behaviour adapted to avoid the extremes of heat and cold in the arid regions (Prakash, 1962; Fitzwater and Prakash, 1969). It is, therefore, expected that climatic fluctuations during a year may not p'ay an important role in influencing the fluctuations in gerbil numbers. The soil characteristics are constant in all the seasons. Only vegetation cover could be one of the factors governing the seasonal fluctuations in gerbil numbers. However, it wou'd appear from Table 12, that when the vegetation cover decreases the gerbil numbers increase. A similar situation was also reported by Ashby (1967) for *Apodemus sylvaticus* in Durham. The availability of green food, however, has been reported to have a direct enhancing effect on the rate of breeding of wild rabbits (Hughes and Rowley, 1965). It was observed in a previous study (Prakash, 1964b) that the rate of littering of *Meriones hurrianae* also increases during the monsoon. This enhance breeding which is apparently due to availability of green food, would explain the peak numbers met with during the winter in two zones. and during spring in Barmer-Gadra Road region. A plausible cause of low numbers during summer could be the low survival of the offsprings delivered after spring as has been observed in the case of the desert hare, *Lepus nigricollis dayanus* (Prakash and Taneja, 1969). Hence the seasonal fluctuations in gerbil numbers are influenced by the rate of breeding which is enhanced by the availability of green food during monsoon.

Rainwater flooding the burrows of fossorial rodents, is another factor which may matter in regu'ating the gerbil numbers. In all the experimental zones their numbers tended to increase after the monsoon and as such it may be difficult to attribute any mortality of gerbil to this limiting factor. Moreover, the burrows of Indian desert gerbils are so extensive (Fitzwater and Prakash, 1969) that the scanty rains of the desert region may not be sufficient to flood their burrow system.

The role of predators, mostly snakes and predatory birds, in regu'ating the gerbil numbers is not clearly known but peak gerbil numbers are met with during the period when the snakes, their chief predators, hibernate. The gerbil population tends to fall after winter when reptiles are active.

To exp'ain the seasonal fluctuations in rodent population is an intricate problem since, in nature, only one factor cannot be held responsible for these changes but several factors working together. Moreover, without studies on their behaviour, genetics and the endocrine mechanism, it is all the more difficult to work out the details of the population turnover.

Replacement of Species

Due to prolonged drought :

Field rodents were collected in the sandy habitat of Udayramsar, 4 km south of Bikaner in Rajasthan during January 1969 and, thereafter, on every third month during 1972, 1973 anl 1974. The results of the trappings made during these two periods form the basis of this report.

Trapping was done with snap traps. 30 in each of four trap lines fixed at intervals of 10 m. Each line was fixed 15 m apart in a homogenous habitat having a more or less uniform vegetation composition. The traps were laid continuously for 72 hours and the trap index was calculated by substracting one half the number of rodents collected from the trap hours (Jackson, 1952).

During the first trapping period (January 1969) four species (Table 13) of rodents were collected from the sandy habitat at Udayramsar. The trap index was calculated to be 4.5 rodents/100 traps/24 hours (Prakash *et al.*, 1971). During the second trapping period, covering 1972, 1973 and 1974, however, only one species, the Hairy footed gerbils, *Gerbillus gleadowi* was found to predominate. The trap index in various months (January, April, July and October in these years) ranged from 0.83 to 11.76 gerbils/100 traps/24 hours.

The data indicate the replacement of the other rodents species of the habitat by the endemic *G. gleadowi* over the study period. Although the breeding potential of *G. gleadowi* is lower than those of *Tatera indica* and *Meriones hurrianae* (Prakash, 1971b) yet the increase in the population size is interesting, particularly under similar ecological conditions.

With our knowledge of the biology, ecology and behaviour of the desert rodents gained over the last two and a half decades, it may be pertinent to speculate on the process of the observed changes in species composition of the habitat. In this context the climatic conditions at Bikaner, particularly the rainfall pattern during the period of the study deserve special consideration. Rainfall plays an important role in controlling (i) the soil moisture status, which in turn influence the microclimate inside the rodent burrows, (ii) the vegetation regeneration, thus affecting the availability of green food, and (iii) indirectly the breeding rate of the desert rodents (Prakash 1960, 1971a). But during the period 1961-1973 it ranged from 50 to 265 mm only always lower than the normal.

Thus, the region may be said to have been experiencing a continuous drought spell since 1961. The average annual rainfall during 1971, 1972 and 1973 had been recorded as 221, 192 and 179 mm respectively, indicating the prevalence of persistent drought conditions in the region. The paucity of rains, which are the only source of water in the desert

Table 13. Per cent frequency of four field rodents in the sandy habitat of the Indian desert (Adapted from Prakash, 1975b)

Species	Per cent frequency in the total collection			
	1969	1972	1973	1974
Meriones hurrianae	20.0	6.6	Nil	1.09
Gerbillus nanus indus	40.0	Nil		1.09
Gerbillus gleadowi	40.0	93 4	100	95.3
Tatera indica	Present	Nil	Nil	1.09

tract reduced the duration of availability of green food for the field rodents. Secondly, prolonged droughts extending over 10 years around Bikaner had permanent'y reduced the perennial flora. Only low yielding, less nutritive annuals, particularly the halophytic plants had survived. Under such aggravated arid conditions only the species which is most adapted to withstand severe fluctuations of temperature and water deprivation and which is highly tolerant to salt in its food, is able to reproduce and survive.

Tatera i. indica was probably evenly distributed in the Indian desert several thousand years ago when climatic conditions in this region were not so severe as they are today. During our ecological surveys, we have found that *T. i. indica* is now found predominantly in the ruderal habitat, i.e. in the village complexes (Prakash *et al.*, 1975b). It, however, also occurs in the natural grasslands and crop fields in the desert. It is speculated that *Tatera i. indica*, due to its relatively poorer adaptability to xeric conditions, must have been the first species either to migrate from or perish in the study area as the continuous drought spells prevailed. *Gerbillus nanus indus*, an endemic subspecies, is likely to have been the next to be replaced. *Gerbillus gleadowi* and *Meriones hurrianae* are well adapted to xeric conditions (Gaur and Ghosh, 1971; Ghosh *et al.*, 1962; Ghosh and Gaur, 1966; Prakash and Rana, 1973). However, the former species is decidedly superior to the latter in its capability to withstand 'dry' environment and is also more salt tolerant. Due to the generally high dissolved salt content of the halophytes, which constitute their major food, and due to gradual increase in soil salinity, it is quite plausible that the population of *Meriones hurrianae* also dwindled to insignificant numbers over the years and only *Gerbillus gleadowi* survived, following the process of natural selection. However, the representation of *G. n. indus*, *T. indica* and *M. hurrianae* during 1974 in small proportion indicates that their population has started building up as in this year precipitation was normal (299 mm) (Prakash, 1975a). Data on subsequent years may reveal certain definite clues to such a change over in the population of these desert rodents. However, work under simulated drought conditions in animal houses using different rodent species is likely to throw more light on the processes underlying species replacements in nature.

During the last 150 years:

A replacement of rodent fauna adapted to xeric environment by that befitting a mesic habitat has been observed in the Indus Basin during the last 150 years, with an admixture of the two faunae in the southern fringes of the Basin where this change over is not yet complete.

The information about the soil type, vegetation and faunal, changes which occurred in the Indus Basin 150-200 years ago, have been taken from the gazetteers and other available literature. The present rodent communities were studied mainly by trapping methods in the Punjab and northern Rajasthan (Mann, 1975, Prakash *et al.*, 1971c).

The changes which have occured in the Indus Basin owing to the man made irrigation systems, turning the desert grazing land into cropland, can be divided into three phases: (a) desert grazing land, at present characterised by the region south of Sri Ganganagar District, which was present in the Indus Basin 150 years B. P. (Anon., 1908; Parker, 1924), (b) the intermediate phase where the change over is not complete and the irrigated cropland system is interspersed with native sand dune and xeric vegetation, represented by Sri Ganganagar District, 50 years B. P., and (c) that of a totally converted irrigated cropland, the present Punjab. A study related to the succession of rodents in the rodent communities by changing land-use pattern was initiated and worked out (Table 14), (Prakash, 1978). This succession pattern suggests that the desert adapted species of rodents having saharian affinities (*Gerbillus, Meriones* and to some extent *Tatera*) have been replaced by *Rattus meltada, Nesokia indica, Mus musculus* and *Mus booduga*. Most of the latter species are oriental in origin. This indicates that no sooner the desert environment (mainly soil and flora) changed to wetter irrigated system, the desert rodents, having saharo-Rajasthan affinities were ousted by the oriental ones. We do find a phase in between the two which is at present existing in the partially modified Sri Ganganagar District wherein both the desertic and mesic elements of rodents co-exist though the frequency of occurrence of the former has been greatly reduced (Prakash, 1978).

Table 14. Succession of rodent communities in the Indus Valley during the 150 years, brought about due to the change in land-use pattern; from a desert grazing land to an irrigated cropland (Prakash, 1978)

Time sequence	Environment type	Rodent communities	Zoo-geographical affinities
At present	Mesic environment, irrigated cropland	*Mus booduga* *Mus musculus* *Nesokia indica* *Rattus meltada*	Oriental Palaeo-tropical Saharo Rajasthani
50 years B.P. intermediate state	Irrigated crop-lands interspersed with original sand dune vegetation	*Nesokia indica* *Rattus meltada* *Tatera indica* *Meriones hurrianae*	Saharo-Rajasthani Oriental Paleotropical Irano-Rajasthani
150 B.P. Xeric	Desert Environment	*Tatera indica* *Meriones hurrianae* *Gerbillus gleadowi* *Gerbillus nanus*	Palaeotropical Irano-Rajasthani Sindo-Rajasthani Saharo-Rajasthani

BURROWS AND THEIR MICROCLIMATE

Burrows

The extensive nature of burrows of the Indian desert gerbil has been mentioned by Wagle (1927a), Petter (1961), Ganguli and Kaul (1962), and Prakash (1962). It was observed that their burrows have no fixed plan and differ as much among themselves in one habitat as in other parts of the desert. The individual burrow systems were mainly of three types: (1) superficial burrows which were upto 3 m long and 5 to 10 cm deep. These were small separate units, usually not inter-connected (Fig 1). The number of such burrows was found to be the highest at Palsana. Such superficial burrows may be of advantage to desert gerbils in escaping predatory birds as the gerbils can duck in them. (2) Shallow burrows usually lead into (3) deep burrows. Some separate shallow burrows were encountered, however. The galleries of these shallow burrows ranged from 10 to 25 cm in depth. A maximum depth of 100 cm for the deep burrows was observed at Bikaner. It was 65 cm at Jaisalmer and 108 cm at Palsana. Soil depth may be a factor governing the maximum depth of burrows for soils at Jaisalmer are shallow but at the two other localities are deep. The maximum depth of the burrows of *M. hurrianae* observed by Petter (1961) at Bender-Abbas was more than 2 m. He further observed that one tunnel of the burrow may be long, separated from others and situated under thickets. The deepest parts of the gerbil burrows at Palsana were usually found under *Zizyphus nummularia* bushes. The deepest part may not consist of a solitary tunnel, as at one point, three stories of a burrow cross over each other. The superficial burrows were devoid of any bolt hole but in other types these emergency escapes were found usually near the burrow openings (Fitzwater and Prakash, 1969).

The burrows of *Meriones hurrianae* were found to be generally more extensive and complicated than those of either of the two nocturnal gerbils inhabiting this desert, viz., the Indian gerbil, *Tatera indica indica* (Prakash, 1962 and the Hairy-footed gerbil, *Gerbillus gleadowi* (Prakash and Purohit, 1966). Although diurnal in nature, *M. hurrianae* usually spends only brief period of time on the surface. Its behaviour in this respect is similar to the Antelope ground squirrel, *Citellus leucurus,* which, according to Schmidt-Nielsen (1964), allows some hyperthermia to develop during surface activities and the excess heat is then in-

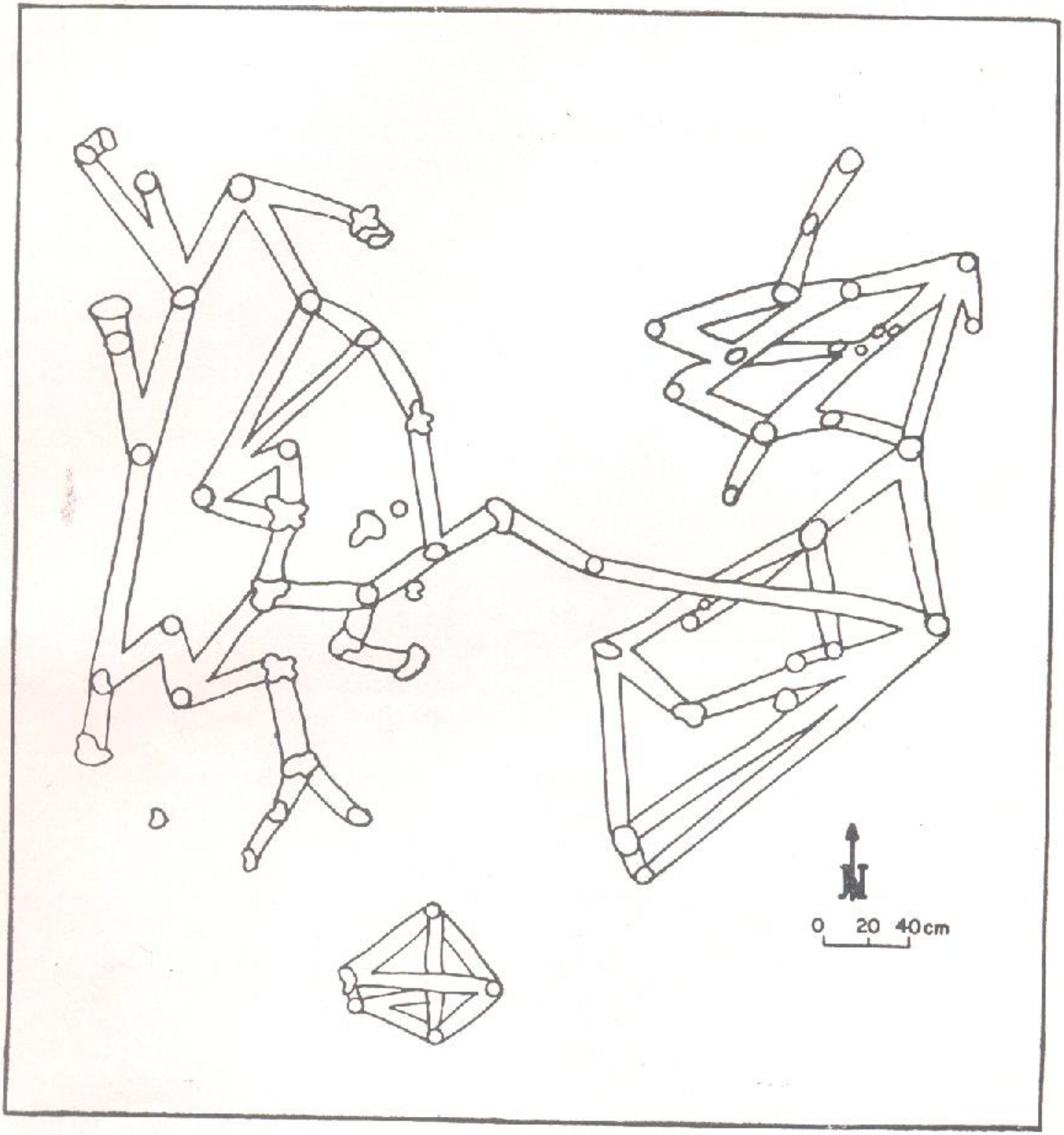


Fig. 1. Burrow system of the desert gerbil.

termittently unloaded to the cooler surroundings (Prakash *et al.*, 1965) of its deep burrow. It seems to be necessary for the burrows of diurnal rodents to be architecturally suitable for efficient thermolysis. The evaluation of the complex and extensive *Meriones* burrows may be taken as an expression of behavioural adaptation in this species for the maintenance of homeostasis.

Burrow Microclimate

Burrow temperatures were measured by Soil Moisture and Temperature Bridge model 200 B and Philips Rod Thermistors type 100-092. The bridge which is Wheatstone type measures the DC resistance of thermistors within the range 23,700 and 5240 ohms, corresponding to 0° and 45°C, respectively, when used with this specific type of thermistor which is supplied with a resistance tolerance of ± 25%. The thermistors were calibrated at different temperatures which were taken into account while recording the final reading. The Philips Rod Thermistor type 100.092 gives temperature readings accurate to ± 0.25°C. It is about 3 cm long and 0.5 cm in diameter and is attached to a wire which is connected to the bridge. Thermistors were inserted in the burrows at various slant depths 50, 100, 150 and 200 cm, corresponding on an average 25, 70, 120 and 150 cm vertical depth, by the following two methods. In straight burrows they were inserted with the help of thick graduated flexible wires. In burrows with bends, the thermistor was tied to the tail of the gerbille by means of a thread. After letting the gerbille inside the burrow, it was stopped at the required depth by holding the graduated thermistor wire. Ther gerbille got rid of the thermistor by cutting the thread. The thermistors were seldom damaged. The hourly observations were taken on two days of every month and there were four replications for each particular depth.

Temperature Outside Burrow

a. Average air temperature—Average hourly air temperatures indicate a well-defined peak corresponding to 4 p.m. during winter, between 4 and 5 p.m. during hot weather, between 3 and 4 p.m. during monsoon, and at 3 p.m. during post-monsoon season (Prakash *et al.*, 1965). The average range of day temperatures during the various seasons is as follows:

	Range (°C)	Actual variation (°C)
Winter	13.1 to 24.8	11.7
Hot weather	28.1 to 39.3	11.2
Monsoon	26.8 to 33.4	6.6
Post-monsoon	19.6 to 32.7	13.1

b. Soil surface temperature—The seasonal and hourly variation are the highest at the soil surface (Table 15). There is a well-defined peak of maximum temperature during all seasons. This occurs at 2 p.m. during winter and hot weather, at 1 p.m. during monsoon, and between 12 noon and 1 p.m. during post-monsoon season; thereby showing that the maximum temperature epoch for soil is generally two to three hours ahead of the maximum temperature epoch of air. The range of soil surface temperatures from

Table 15. Hourly air temperatures (°C) and hourly temperatures (°C) at soil surface and at various burrow depths (adapted from Prakash *et al.*, 1965)

	Temperatures (°C) at the following hours of the day												
	07.00	08.00	09.00	10.00	11.00	12.00	13.00	14.00	15.00	16.00	17.00	18.00	19.00
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)
WINTER													
Normal air (average for 1948-52)	13.1	13.1	14.8	17.5	20.7	22.3	23.6	24.1	24.7	24.8	24.5	23.3	21.4
Soil surface	—	11.9	18.5	26.9	34.1	37.1	38.1	39.0	37.1	32.4	28.4	23.2	16.8
50 cm	20.1	19.9	20.3	20.3	20.2	20.0	20.1	20.6	20.9	20.9	20.9	21.0	21.1
100 cm	20.5	19.2	19.1	19.2	19.2	19.2	19.3	19.1	19.3	19.5	19.6	19.8	19.8
150 cm	20.3	19.4	19.6	19.3	19.2	19.3	19.6	20.0	20.2	20.4	20.5	20.6	20.7
200 cm	19.8	19.6	19.3	19.2	19.2	19.1	19.3	19.4	20.8	20.2	20.3	20.4	20.6
HOT WEATHER													
Normal air (average for 1948-52)	28.1	29.4	31.4	33.2	34.7	36.6	37.7	38.6	39.1	39.3	39.3	38.6	37.1
Soil surface	26.7	32.3	37.3	42.0	46.9	49.5	54.0	55.5	51.5	45.7	42.8	39.3	37.0
50 cm	35.3	35.2	35.2	35.4	35.4	35.3	35.4	35.6	36.2	36.6	37.0	37.6	37.6
100 cm	33.6	34.7	34.7	34.8	34.9	34.8	34.9	34.7	34.8	35.0	35.2	35.2	35.0
150 cm	33.9	34.0	33.9	34.0	34.0	33.9	34.2	34.2	34.4	34.6	34.7	35.1	35.4
200 cm	34.5	34.5	34.4	34.5	34.2	34.4	34.3	34.5	34.7	34.8	34.9	35.3	35.3
MONSOON													
Normal air (average for 1948-52)	26.8	27.5	28.4	29.6	30.7	31.3	32.4	33.1	33.4	33.4	33.2	32.0	31.3
Soil surface	32.1	32.6	34.3	37.7	41.9	44.8	45.8	39.7	38.4	37.6	35.7	33.9	31.5
50 cm	28.5	30.1	30.8	31.5	32.3	33.5	34.3	33.3	32.5	32.0	32.1	32.7	31.6
100 cm	27.6	29.2	31.6	31.8	32.2	32.7	34.3	33.9	34.3	35.0	34.9	34.9	35.3
150 cm	32.9	34.5	34.1	34.2	34.3	34.4	34.6	35.2	35.2	35.4	35.5	35.8	35.7
200 cm	—	—	—	—	—	—	—	—	—	—	—	—	—

POST-MONSOON

Normal air (average for 1948-52)	19.6	20.6	23.4	26.2	29.2	31.1	32.1	32.5	32.7	32.5	31.7	30.4	28.1
Soil surface	22.7	23.1	30.9	39.1	43.4	49.3	49.3	47.9	44.9	39.7	33.1	25.8	24.5
50 cm	24.6	24.7	24.6	24.7	24.7	24.9	25.7	25.4	25.1	25.2	25.3	25.5	25.5
100 cm	27.9	28.0	28.1	28.1	28.1	28.1	28.1	28.2	28.3	28.3	28.6	28.7	28.7
150 cm	31.2	31.3	31.3	31.1	31.1	31.0	30.9	30.8	30.7	30.9	30.9	30.4	30.4
200 cm	29.6	29.7	29.6	29.3	29.3	29.1	29.1	29.2	29.2	29.5	29.7	29.8	29.9

7 a.m. to 7 p.m. recorded during various seasons is as fol'ows:

	Range (°C)	Actual variation (°C)
Winter	11.9 to 39.0	27.1
Hot weather	26.7 to 55.5	28.8
Monsoon	31.5 to 45.8	14.3
Post-monsoon	22.7 to 49.3	26.6

Burrow Temperature

In contrast to the air and soil surface temperatures, there is very little hour-to-hour variation of temperatures inside the burrows during the various seasons (Fig. 2, 3). The variation of temperature from season to season is also considerably less at all depths. There is no well-defined peak of maximum temperature inside the burrows except in the monsoon and post-monsoon seasons, when a peak is noticed at 50 cm depth and corresponding to 1 p.m. Generally the burrow temperatures tend to increase during the last afternoon, after 5 p.m. In winter the burrow temperatures are not only higher during the late afternoon but also at 7 a.m., thereby indicating that the burrow is probably uniformly warmer during the night when air and surface temperatures fall considerably, and the gerbil has not to encounter the chilly cold winter night. It is further observed from Table 15 that in winter, the burrow temperatures averaged over all depths are warmer than the normal air temperature from 7 a.m. to 10 a.m. by 2.0 to 7.1°C., and warmer than soil surface by 1.1 to 7.6°C from 7 a.m. to 9 a.m., and by 3.7°C at 7 p.m. In the hot weather, the burrow temperatures are in the range of 33.6 to 37.6 considering all depths, whereas the soil surface temperatures reach as high as 55.5°C. These features indicate clearly that the burrows serve the gerbil as air-conditioned chambers to avoid the high extremes of temperatures noticed in the arid region. Very little variation with respect to depth is noticed in the burrow temperatures. There is, however, a slight indication of temperature decrease with depth during winter and hot weather periods and of increase with depth during the other seasons. The range of the day temperatures at various depths in the burrows is given below for various seasons:

It is interesting to note that the burrow temperatures which have generally a small range, varying from 1 to 2°C show a considerable increase in range during

Slant depth	Winter	Hot weather	Monsoon	Post-monsoon
50 cm.	19.9 to 21.1 (1.2)	35.2 to 37.6 (2.4)	28.5 to 34.3 (5.8)	24.6 to 25.7 (1.1)
100 cm.	19.1 to 20.5 (1.4)	33.6 to 35.2 (1.6)	27.6 to 35.3 (7.7)	27.9 to 28.7 (0.8)
150 cm.	19.2 to 20.7 (1.5)	33.9 to 35.4 (1.5)	32.9 to 35.8 (2.9)	30.4 to 31.3 (0.9)
200 cm.	19.1 to 20.6 (1.5)	34.2 to 35.3 (1.1)	—— ——	29.1 to 29.9 (0.8)

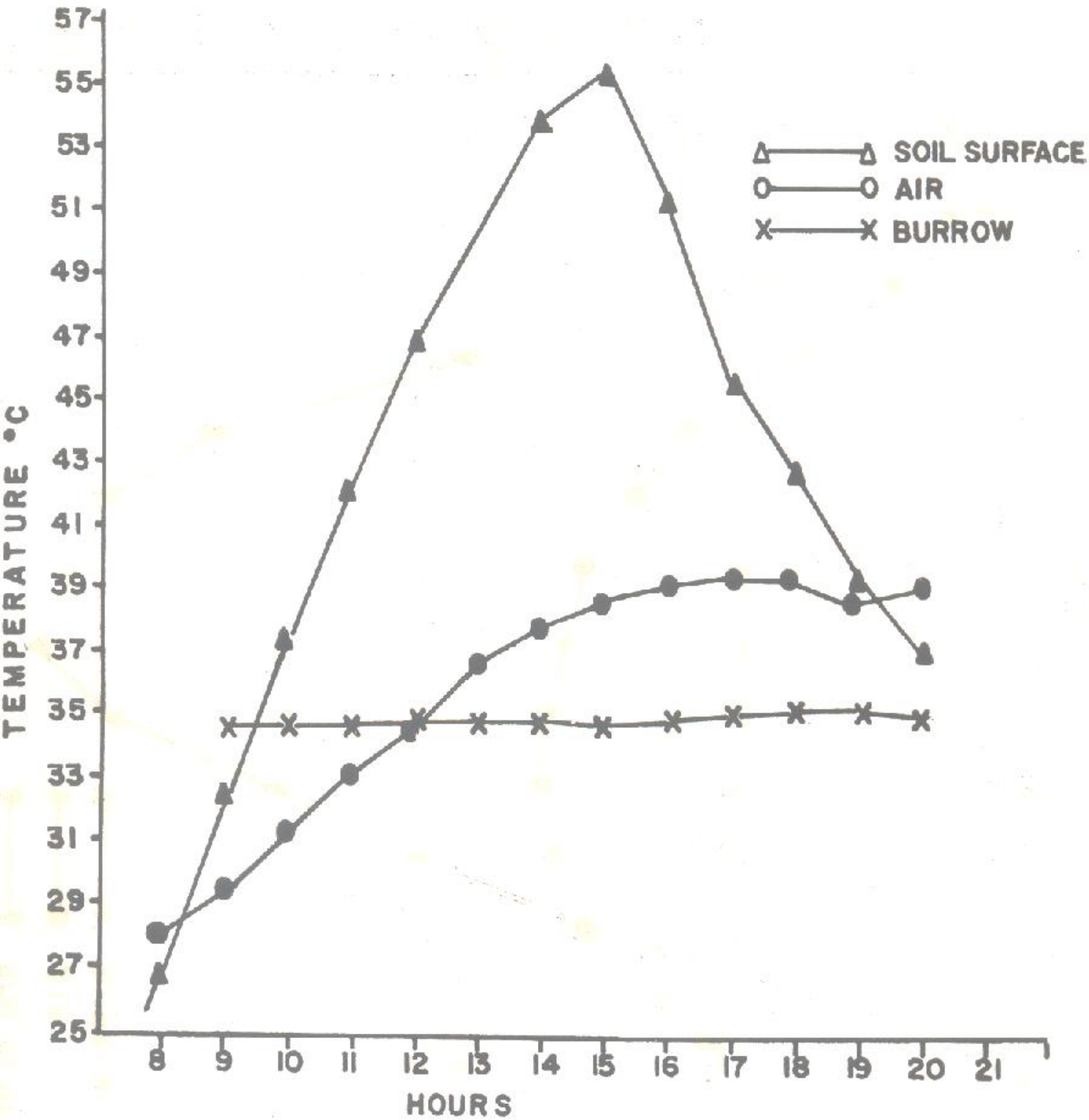


Fig. 2. Diurnal variations of air temperature and that at soil surface and inside burrow during summer.

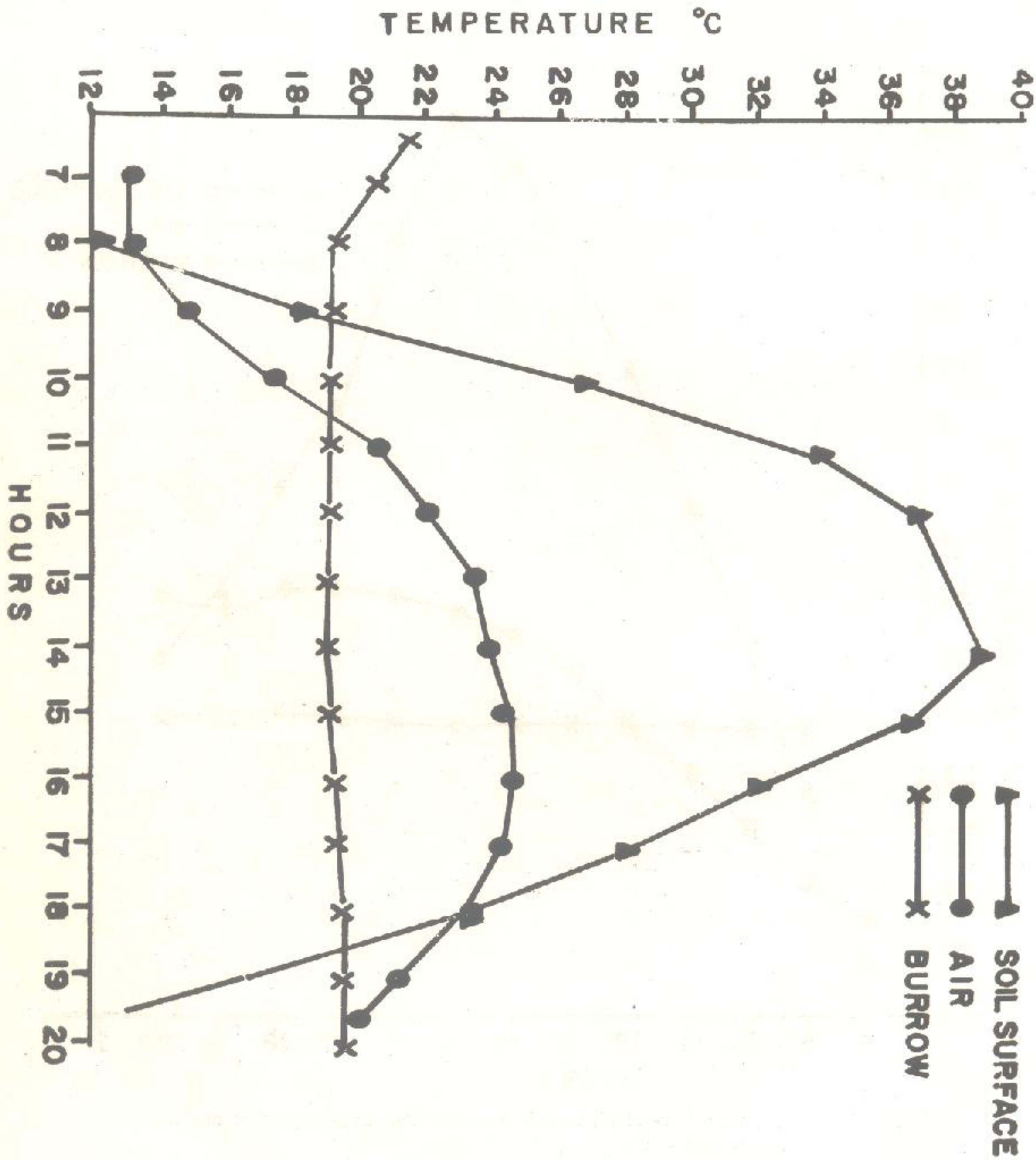


Fig. 3. Diurnal variations of air temperature and that at soil surface and inside the burrow during winter.

the monsoon when the air and soil temperatures have the minimum range. The increase in range inside the burrows during this season may be attributed to the occasional flooding of the burrows with rain water (Prakash *et al.*, 1965). Table 16 gives the normal air temperatures and the burrow temperature averaged for the four depths at the time of maximum temperature epoch of the soil maximum temperatures recorded during various seasons.

Table 16 shows that, at the time of maximum temperature epoch of the soil surface temperature, burrows are cooler than the soil surface by 19.2° to 20.9°C. in various seasons except in the monsoon when the difference is 11.4°C, whereas the air temperatures are less than the surface temperature by 13.4° during monsoon and from 14.9° to 17.7°C during other seasons. This also indicate that the burrows help the gerbils in avoiding the extreme temperatures of the desert.

Table 16. The air and burrow temperature at the maximum temperature epoch of the soil surface during different seasons (adopted from Prakash *et al.*, 1965)

	Winter 2 p.m. °C	Hot weather 2 p.m. °C	Monsoon 1 p.m. °C	Post–monsoon 12 & 1 p.m. °C
Soil surface	39.0	55.5	45.8	49.3
Normal air	24.1	38.6	32.4	31.6
Burrow temperature averaged for the four depths	19.8	34.7	34.4	28.4
Difference between soil surface and average burrow temperature	19.2	20.8	11.4	20.9
Difference between soil surface and normal air temperature	14.9	16.9	13.4	17.7

BEHAVIOURAL PATTERNS

Meriones hurrianae exhibits different behavioural patterns, which can be attributed to (i) individualistic behaviour specific in nature and (ii) behaviour that adapts the individual with the external environment, making its survival a success in the harsh desertic conditions. By observations with the help of binoculars behaviour of the desert gerbil was studied and the salient findings are enumerated below.

Auditory Communication

M. hurrianae communicates through squeaks when they are trapped and when they are given a hot chase by another merion gerbil. While handling them in laboratory also they emit a long shrill call, though it is not as loud as that of squirrels.

It was observed that *M. hurrianae* are not disturbed by an approaching man who is 3-4 m far, but no sooner he scratches the soil surface or makes a noise with the foot, it is quickly perceived and the entire colony ducks in the burrows, suggesting that the sound travelling through sand is perceived quickly (Prakash, 1959a), than that through air; or that the auditory faculty in this gerbil is much more efficient than the visual one.

Contrary to the conjecture that their perception of sound travelling through solid, soil medium is stronger, we also observed (Fitzwater and Prakash, 1969) that the noise of wing beats of the predatory birds, Pariah kites (*Milvus migrans*), shikra (*Austur badius*), Tawny eagle (*Aquila rapax*), and the house crow (*Corvus solendens*) are quickly perceived by the merion gerbils and they take shelter in the burrows. Interestingly, the sounds of wing beats of babblers (*Turdoides* spp.), pigeons (*Columba livia*), and doves (*Streptopelia* spp.) which are not predatory, never disturb them. It may indicate that the desert gerbils can possibly differentiate between the wingbeat noises of harmless and predatory birds. This specialized differentiation may be achieved due to the hypertrophied tympanic bullae. The length of tympanic bulla of *M. hurrianae* is 35.4 per cent (Table 17) of the condylobasal length of the skull, which indicates that their tympanic bullae are enlarged (as compared to those of rodent species inhabiting humid climate; Prakash, 1959a). and probably help the gerbils in detection and differentiation of various types of sounds. It has also been suggested that the hypertrophised tympanic bullae might act as resonators, amplify the sound

Table 17. Hypertrophy of tympanic bulla in mammals (after Prakash, 1959a)

Mammal species	Cranial measurements (in mm.)							
	op	cb	al	%	ltb	%	btb	%
			DESERT BIOME					
Indian gerbil, *Tatera indica indica* Kerr (10)	39.8–43,0 41.2	40.0–41.8 31.3	13.0 13.0	31.7	12.0–13.0 12.3	30 3	7.0–7.8 7.2	17.5
Indian desert gerbil *Meriones hurrianae* Jerdon (6)	30.5–34.0 32.8	30 0–32.0 31.3	10.0–10.8 10.3	32.8	10.5–12.0 11.1	35.4	8.0–8.8 8.3	26.5
			MESIC BIOME					
Indian Mole rat, *Bandicota bengalensis bengalensis* (Gr. & Hardw.) (6)	40.7–45.3 42.5	40.0–44.5 41.8	9.9–11.1 10.6	25.3	6.4–7.4 6.9	16.5	—	—
Manipur Rat *Rattus manipulus kekrimus* Roonwal (4)	36.2–39.8 37.5	35.6–38.7 36.9	8.6–9.0 8.8	23.9	5.8 5.8	15.9	—	—
Blanford's Rat *Rattus blanfordi blanfordi* Thomas (1)	43.5	43.0	10.5	22.0	8.0	18.5	4.0	9.3

vibrations and enhance the perception. The hypertrophy of tympanic bullae is regarded to be an adaptation to increased perceptibility of mating calls, and sounds of movements of snakes and predatory birds (Webster, 1960; Petter, 1961). However, Bodenheimer (1957) suspected that this hypertrophy is obviously primarily a morphological reaction to the dry environment.

Digging Behaviour

The mode of digging burrows by merion gerbil is slightly different than that in *Tatera i. indica* and *Gerbillus nanus indus*. *M. hurrianae* digs a few shallow pits, about 1 to 2 cm deep and 2-3 cm in diameter by the front paws. Then it deepens one of them digging by front paws and shovelling the earth by the hind limbs. When a tunnel has been dug, about 1 to $1^1/_2$ m long, the desert gerbil moves about to a distance of 1-2 m and starts digging another tunnel which leads towards the previous one and later on is connected with it. A complex burrow system is gradually built in this manner. The merion gerbil never digs from inside to outside.

Foot-Thumping or Drumming

The desert gerbil thumps on the sand, or the surface of cage under several situations, almost invariably signifying danger and it is thus regarded as an alarm signal. The continuous thumping noise (drumming) is produced by striking one of the hind feet on the ground with great speed. In the field observations, it was observed that no sooner the gerbil was live trapped it produced the drumming noise in the trap and as a consequence all the desert gerbils in the area took refuge inside the burrows. This drumming is not produced while one gerbil is chased by another of the same species. Any loud noise, such as report of the gun, also initiates the drumming activity. During mating also, thumping is done by male possibly to warn off other gerbils in the surrounding area. This thumping lasts for 0.3/sec on an average. Cowan (in press) has also explained this foot-thumping as a response to disturbance.

Washing (or) Grooming

Most of the desert rodents, particularly the desert gerbils clean their body surface quite often. Cleaning of paws, the hind ventral and lateral portions of the body is achieved with the help of the incisors assisted by the lips. The tail is cleaned by holding it in between the front paws and by nibbling it from the proximal to distal end. The gerbils clean the face, eyes and vibrissae with fore paws, and the proximal portion of thorax and lateral sides of the body with the hind paws. The ears and other parts of body are frequently scratched by the hind paws.

Sand Bathing

Sand bathing is also a part of grooming to remove damp and sticky material from the fur. This behaviour was observed in laboratory cages. When the gerbils are wet, usually due to sprinkling of water, they perform the sand-bathing sequence. The desert gerbil pushes the soil forward with the help of muzzle and ventral side of chin, and rubs the belly against the soil. It performs side rolls and rubs it on the soil surface 3-5 times, rolls on the dorsum and rubs the other sides. Sometimes, the gerbils try to rub the dorsum also. During this behaviour the body is fully extended and the limbs are drawn outwards. *G. n. indus* keeps the tail upwards during this sequence. Sand bathing is noted to be a trait shared by all desert-adapted rodents (Eisenberg, 1967). The desert rodents have increased sebaceous secretion to reduce the evaporative water loss through the epidermis. The increased sebaceous secretion leads to dressing the palage by means of sand bathing. Further, a relatively stereotyped pattern with species specificity has been recorded (Eisenberg, 1963).

Marking Behaviour

In the wooden box, in 30 minutes, 37 out of 38 males and only 11 out of 28 females marked at least once ($x^2 = 27.42$, $P<0.01$). Marking frequency varied widely against individuals, though adult males (median marking score 8; range 0.27) even when females which marked at least once are considered separately (median 2; range 1-12, $P<0.01$). Encounters were then staged between adult males, adult females, and adult males and females; fighting occurred in all three types of encounter, but was less frequent among females (Kumari *et al.*, 1979).

Fighting resulted in tremendous increase in the marking rate of the 'dominant' gerbil in each encounter. For example, in the 30 minutes before the encounters, male marked with median score-7. During a 15 min encounter, the gerbil which was 'dominant' marked with median score-19. The 'submissive' gerbil made O marks and marking behaviour was completely inhibited. Observations on territorial marking rate in both sexes of *M. unguiculatus* (Thiessen *et al.*, 1971) is similar to that of marking rate in *M. hurrianae*. However, the functional significance of this marking still remains obscure.

In nature, ventral marking largely occurs on mounds of sand around burrow entrances and along sandy trails between frequently used burrow systems supporting the observations made by Fitzwater and Prakash (1969) that *M. hurrianae* defend only frequently used burrow areas within the more extensive home ranges. The function of this marking may be to identify "home" as opposed to "foreign" habitat and consequently the constant re-marking of familiar areas may be due to constant erosion of sand by wind action.

Swimming

All the gerbils can swim, although such occasions are rare in the desert. They swim within fore and aft motion of the limbs. Generally, they keep their head above the surface of water and the tail remains parallel to the body which is kept initially at an angle of 45° to the surface. But as the time passes they get tired, the angle of body increases and subsequently they get drowned. *Tatera indica* is a better swimmer than *M. hurrianae*.

Exploratory Behaviour

The exploratory behaviour was studied in plus mazes. Six individual *M. hurrianae* (3 male, 3 female) were released in separate maze (Advani and Prakash, 1979a/b). Daily records were taken for

a) total number of visits and total time spent in each part of the maze, b) route of animal's movement, c) total daily consumption of food and water, d) general activities and activities performed by rodents as feeding, drinking, sniffing, grooming, nesting, yawning, sleeping, sandbathing, chewing, digging, etc. The time spent during all these activities and behavioural trails performed were also recorded separately.

The results have indicated that the exploratory behaviour of both sexes of *M. hurrianae* declines gradually with time, it becomes familiar with the new environment. When the items (food, water and cork for chewing) were transferred from one arm to other, the exploratory activity shot up as indicated by increase in total number of visits. This exploratory behaviour gives a sort of protection to the individua's in the novel or strange surroundings. The ranging movements during the exploration though seem to be aimless, in fact, can provide the animal with information which may be used later. An invisible change takes place during exploration and is called latent or exploratory learning (Barnett, 1966). These movements brings about the familiarity with the surroundings, as such, very useful in the natural conditions in avoiding predators.

Territorial Behaviour and Home Range

Methods: The gerbils were trapped with Sherman traps, sexed, numbered by toe- clipping and released at the capture point. The marked gerbils were also observed with the help of binoculars. The home ranges were drawn using the method of Burt (1940, 1943). The home ranges of six females and three males were calculated.

Territorial behaviour : Inter and intra sexual fights and chasings were observed in the study plot. After a few chases the gerbils tolerated each other and spent most of the morning feeding. However, when they are approached in vicinity of the other, they threw on each other dirt with their hind feet, which may be an indication of territorial behaviour among the desert gerbils (Fitzwater and Prakash, 1969). It appears that desert gerbils usually adjust to the presence of each other but maintain a distance of about two to four metres apart. Defence of a territory is initiated only when another member tries to cross these limits. The overlapping ranges of male and female desert gerbils also suggest that they do not defend their entire range but protect the immediate vicinity of the burrow openings near which they use more frequently.

Home range: Almost all the ranges of both male and female desert gerbils were overlapping (Figs. 4 and 5) and in no case was a clear cut range exclusively occupied by a single gerbil. The range remained similar during March-April, when no mating was observed and in June-July when mating was observed, with the exception of one male. Since particular male was observed to mate with a number of females at distant locations, it seems likely that it had extended its movements in quest of suitable females for mating purposes. If the extension of male desert gerbils is calculated to be 159.4 ± 44.3 sq m otherwise it is 88.7 ± 14.3 sq m. However, neither of the figures is significantly different from the

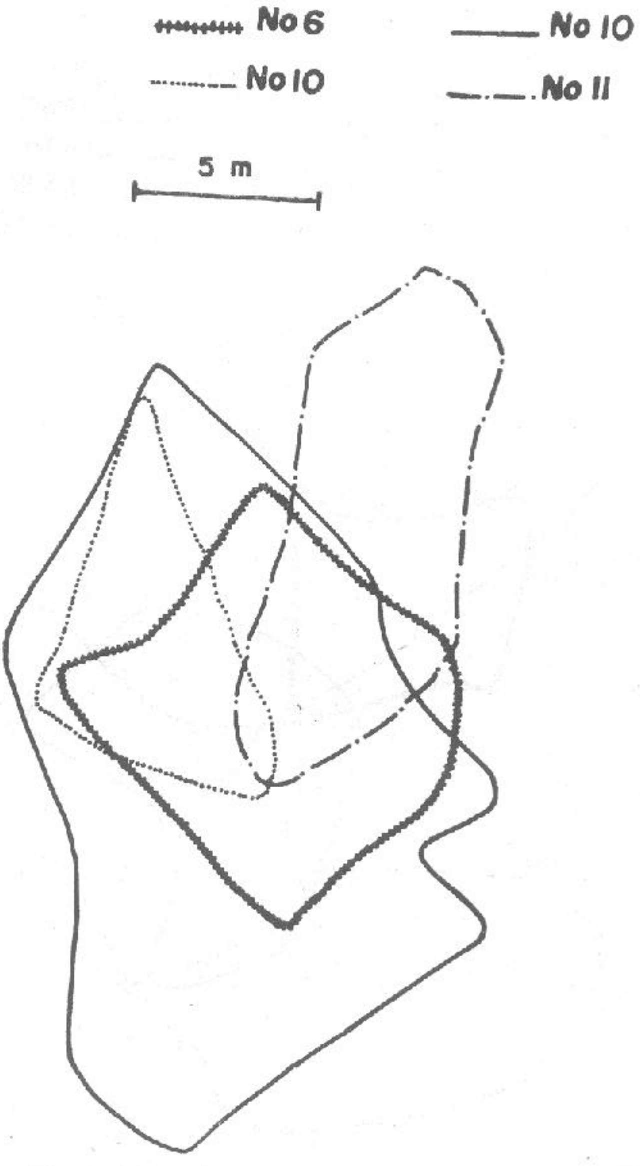


Fig. 4. Observed home range of male desert gerbils.

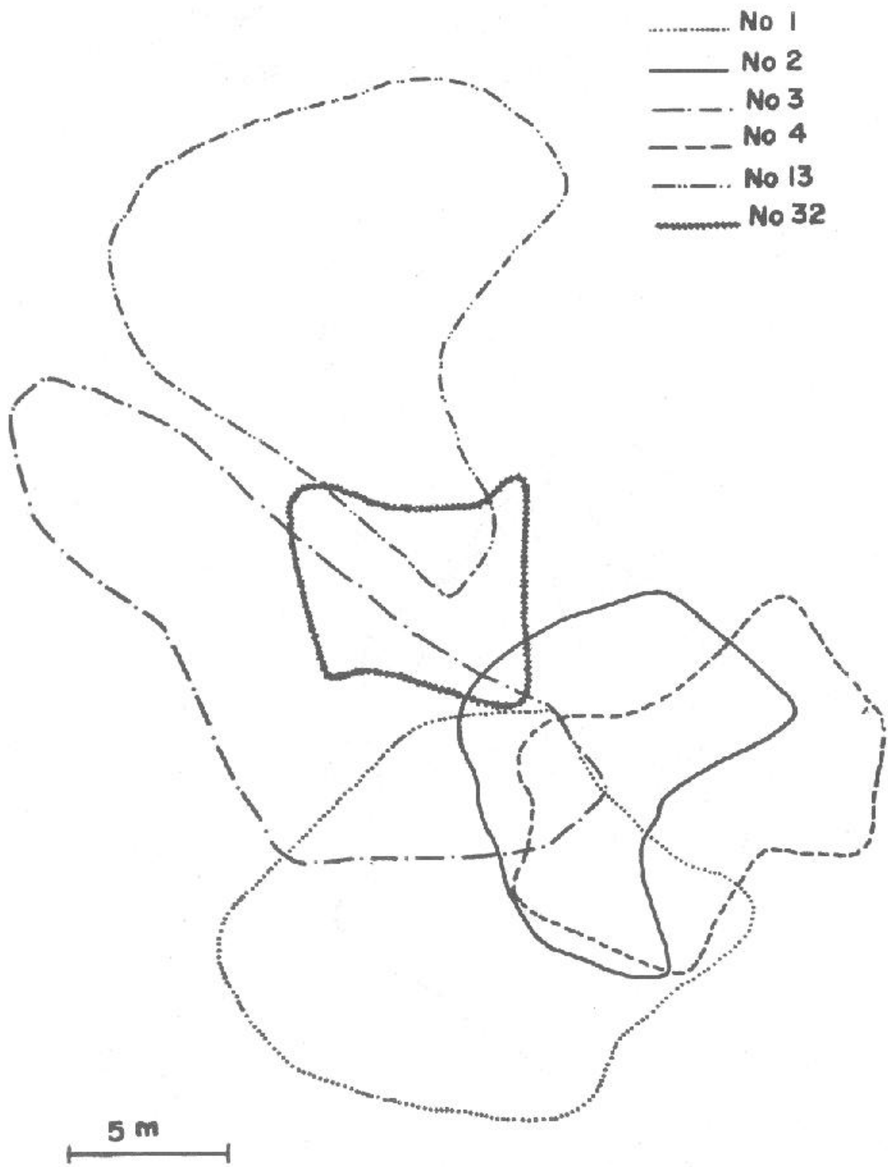


Fig. 5. Observed home range of female desert gerbils.

average female home range of 154.7 ± 24.6 sqm (Fitzwater and Prakash, 1969).

The observed range lengths of female gerbils averaged 18.46±1.5 m as compared to that of the male gerbils, viz., 16.03±0.98 m (20.3±2.9 m when the movements of male No. 10 are considered). These range lengths are not significantly different from each other.

From these data it appears that the range of movement of desert gerbils is quite restricted and poison-bait stations could be established at 10 metre intervals. Due to overlapping of home ranges each poison station can be expected to provide material for more than one gerbil.

Neophobia and New Object Reaction

M. hurrianae displays avoidance of the novel stimuli in familiar environment (Advani and Prakash, 1979a). This phenomenon, called as neophobia persists for 2 to 8 days. The results indicated that gerbils when exposed to a new object in its general area of movement as judged by the amount of food consumption prior to and after the exposure. Another study by measuring the daily intake of water also confirmed this behaviour in the merion gerbils. This neophobic behaviour may be a component associated in the trap shyness (Ryley, 1913; Prakash, 1964b). These rodents also exhibit new place reaction. Another study by Mathur and Prakash (1979) indicated new food reaction by the merion gerbil when a different food was exposed to them. However, the reaction is not so pronounced as in *T. indica,* another co-existing species in its habitat. The reaction vanished after three days, pointing a 3-day period of prebaiting before poison baiting.

Bait Shyness and Poison Aversion

It is an established fact that during rodent control operations, those rodents which consume sublethal dose of poison and recover after a period of sickness can associate the sickness with the bait and even with its individual components and reject such food on subsequent occasions (Rzoska, 1954). The experiments on the desert gerbil with one day exposure to poisoned food represent a specific aversion to the base in which the poison was mixed. This bait shyness is noted to persist upto 35 days after the initial exposure to the poisoned food (Prakash and Jain, 1971). This behavioural trait affords a natural protection to these gerbils when they sample little quantities of poison mixed bait material or toxic plants.

FOOD

Food in Nature

Comber (1910) witnessed a gerbil, *M. hurrianae* feeding on human faeces. Phillips (1923) writes that *T. ceylonica* are particularly fond of raw meat and insect food, devouring cockroaches and beetles with relish, and are also very partial to birds' eggs. They also kill and eat mammals. McCann (1927) reports that their favourable diet is *jowar* and paddy but it took grasshoppers with 'great relish'. Wagle (1927b) concludes that *M. hurrianae* are quite harmless from a farmer's point of view as they feed entirely on the weeds growing around their burrow. They were never found in the rice fields nor had stores of rice plants in their burrows. Prasad (1954a) found a seasonal variation in the food eaten by the gerbil *T. i. cuvieri*. Seeds form a predominant food during December, January and February and to a lesser extent at the sowing season (June-July). In hot weather from April to May and in August-September, the rhizomes of a variety of grasses form an important food item. Insects are also eaten in all the seasons.

Stomach Contents Analysis

Methods: For the examination of stomach contents, the rodents were usually collected just after their feeding time and the contents were taken out. It was quite difficult to identify the plant species since rodents chew them to small bits. Specific determination of plants and animals was made as follows: seeds by their hard coat, stem pieces by their colour and vascular system, leaves by their colours and veins, rhizomes of grasses by their roots and insects by their wings, appendages and other chitinous fragments. The stomach contents were analysed by the Volume method (Hynes, 1950). Contents of all the stomach of gerbils collected in one month were mixed sorted and the volume of each food item was taken and are plotted against the months of the year (Prakash, 1957, 1962).

Seasonal Composition

January-February-March. — Seeds constitute the greater percentage of the food of this gerbil in this season. By the end of this period (March), the percentage of the seeds decreases while that of stems and rhizomes increases. Parts of the following plants were found in their stomachs: *Occulus villosus, Tephrosia purpurea, Zizyphus numularia, Cenchrus biflorus, Boerhaavia diffusa, Eragrotis ciliaris, Spirobolus sp., Capparis aphylla.*

April-May-June. — Severe conditions prevail in these months. Seed percentage in the foods of the desert gerbils decreases considerably and that of stems and rhizomes increases to 45 per cent (Table 18). However, the invarsions of locusts start and these gerbils also start feeding on them and a small number of ants and beetles is also taken. Insects constitute 15 per cent of their food. The following plant species were identified from their stomachs in this period of the year: *Pennisetum typhoidium, Citrullus colocynthis, Cyperus* sp., *Cynodon dactylon, Eragrostis ciliaris, Cenchrus biflorus, C. setigerus, Trianthema monogyma, Boerhaavia diffusa, Crotalaria* sp., *Cucumis terigonus.*

July-August-September. — During this period leaves form the larger part of their food (25-30 p.c.) and also the stems (20-30 p.c.). The percentage of the seeds remains almost constant (20 per cent). In these months *M. hurrianae* consume locusts in sufficient quantity. The plants identified from their stomachs were the same as in April-June period.

October-November-December. — The percentage of the seeds in the stomachs increases in this period from 30 to 60. Stems and rhizomes decrease to 10 per cent. The plants identified were as follows: *Zizyphus nummularia, Capparis aphylla, Cenchrus biflorus, Cucumis terigonus, Citrullus colocynthis* and *C. vulgaris.*

Seasonal fluctuations

The desert gerbil, *Meriones hurrianae* shows considerable variation in food items (Table 18) during the year. Seeds are eaten up to 60 per cent in January, whereafter their percentage decreases to 10 per cent in July but again increases to 60 per cent in December. The decrease of seed percentage coincides with the increase in the percentage of stems and rhizomes in June which goes up to 45 per cent from 10 p.c. in January. Leaves and flowers constitute only 5 p.c. of food in May but during the third period of the year their consumption is maximum. Insects are taken only when other food is in-sufficient and particularly when locusts are abundant (Prakash, 1962).

A comparison of stomach contents of Desert gerbil with that of Indian gerbil, *Tatera i. indica* shows considerable disparity in their feeding time—*Meriones* feeds during the day while *Tatera* during the night. The fluctuations in each food item are reflections of the seasonal changes depending upon the factors of availability and quantity. Seeds are eaten least or not at all by them in June and July, while maximum in December and January. The minimum for *M. hurrianae* is 10 per cent of the entire food in June and that of *T. indica* is nil in July. The maximum, however, differs much. It is 60 p.c. for the former in December and January while it is only 40 p.c. during the same period for the latter. Stems and rhizomes from the stomach contents of *T. indica* do not show appreciable fluctuation (15 to 30 p.c.) as compared to *M. hurrianae*, 10 per cent in January and 45 p.c. in June. Leaves and flowers in the case of *T. indica* range from 20 to 30 per cent throughout the year but in the case of *M. hurrianae* their percentage goes down to 5 in May and reaches 40 in October. The percentage of insects remains nil all the year round except in the months when locusts are available to *M hurrianae* but they form a regular food

Table 18. Showing the percentage of stomach contents of *Meriones hurrianae* during 1954 (Figures in parenthesis are the number of stomachs examined in each month) (Prakash, 1959b)

	Months											
	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sep.	Oct.	Nov.	Dec.
No. of stomachs	(17)	(14)	(19)	(9)	(9)	(4)	(11)	(17)	(25)	(13)	(18)	(16)
Stomach contents :												
Seeds	60	50	40	30	20	10	20	20	20	30	50	60
Stems and rhizomes	10	15	25	35	40	45	30	20	25	20	15	10
Leaves and rhizomes	25	25	15	10	5	15	25	35	30	40	30	30
Insects	0	0	0	5	15	15	15	10	10	0	0	0
Miscellaneous	5	10	10	20	20	15	10	15	10	10	5	0

for *Tatera* and are consumed most in July (40 p.c.).

IDENTIFICATION OF UNCONSUMED PLANTS NEAR BURROW OPENINGS

During field observations, it was noticed that while consuming plants, the rodents leave identifiable portions near their burrow openings during the monsoon season, the main flowering season for herbs in the desert. A study was conducted to assess the food preference of *M. hurrianae* in field by comparing the frequency of unconsumed plants with that in natural plant communities (Prakash, 1969).

Methods

Plant remains were identified and the number occurring near each burrow opening was recorded. In one plant community observations were taken around 20 to 30 burrow openings. The composition of the vegetation was studied by line intercept method and frequency of occurrence of that species found unconsumed near gerbil burrow openings. If the latter was more than twice its occurrence in the surrounding vegetational community, that species was regarded as 'most preferred'; if less than twice 'preferred', if less than its occurrence in the community but not less than 50 per cent 'less preferred', and if less than 50 per cent then 'not preferred'. Each of the above four palatability class was awarded the numerical scores of 4, 3, 2 and 1, respectively. To find out the palatability index of various food species the numerical scores denoting the various palatability classes were added for species occurring in more than two communities and an average was found out.

Observations were also made with a 10 x 40 binoculars on gerbils feeding on various identified plant species.

All these observations were made during the monsoon season at Maulasar in a fenced area of 72 hectares. This area lies in a tract with an average annual rainfall of 400 mm, in the Nagaur District of Western Rajasthan.

UNCONSUMED PLANT SPECIES LYING NEAR BURROW OPENINGS

The observations were taken in four plant communities found in the area:

(a) *Cenchrus ciliaris–Cyperus arenarius—Eleusine compressa—Phaseolus trilobus* community—The community was situated on a low lying sandy plain and the species comprising this community had a frequency of 75 per cent in the transects. The other species in this community having a frequency of 50 per cent were *Justicia vahlii*, *Digitaria adscendens*, *Tephrosia purpurea* and *Boerhavia diffusa*. *Cenchrus ciliaris*, although forming 14.0 per cent of the vegetation in this community, constituted 69.2 per cent of plant species found unconsumed near burrow openings (Table 19). It was the most preferred species. *Cyperus arenarius* and *Aristida adscensionis* although having a low per cent of incidence in nature (0.66 and 2.0 per cent only) yet formed 7.7 per cent of the gerbil food indicating a high preference for these. *Eleusine compressa* on the other hand formed 10.6 per cent of the community and formed only 7.7 per cent of the rod-

Table 19. Per cent occurrence of unconsumed plant species near gerbil burrow openings and in nature, and their palatability classes in the plant community (Prakash, 1969)

Plant species	Per cent occurrence		Palatability Classes
	Unconsumed plant species near burrow openings	in nature	
Cenchrus ciliaris	69.2	14.0	most preferred
Eleusine compressa	7.7	10.6	less preferred
Aristida adscensionis	7.7	2.0	most preferred
Cyperur arenarius	7.7	0.66	most preferred
Digitaria adscendens	3.8	2.6	preferred
Eragrostis ciliaris	3.8	0.66	most preferred

ent diet. It is worth noting that the plant *Phaseolus triolobus* and those having 50 per cent frequency were completely absent from the gerbil menu indicating that they are unpalatable to gerbils. This may also be due to the higher availability of *Cenchrus ciliaris* which forms the majority of the gerbil food in this plant community. 92.2 per cent of the food species were grasses (*Poaceae*).

(b) *Digitaria adscendens—Perotis hordeiformis—Brachiaria ramosa—Eragrostis ciliaris* community—The community was found on a stabilised sand dune. The four species forming the community had a frequency of 83.3 per cent and the others having a frequency of 66.6 per cent were: *Tribulus terrestris* and *Justicia vahlii;* and those having a frequency of 50 per cent were: *Cyperus arenarius, Heliotropium marifolium, Cenchrus biflorus. Tragus racemosus, Aristida adscensionis* and *Corchorus* sp. In this community *Cenchrus ciliaris* inspite of having a low (1.8 per cent) occurrence in nature constituted 18.6 per cent of the food species, while *Digitaria adscendens*, which had the maximum occurrence of 17.3 per cent in nature, constituted 21.3 per cent of the rodent menu (Table 20), showing that the former species is more preferred. On the other hand, the occurrence of *Tribulus terrestris* was 12.0 per cent in nature and it constituted only 2.6 per cent of gerbil food. *Brachiaria ramosa* and *Perotis hordeiformis* having higher frequency were rated as less preferred and not preferred, although their occurrence percentages were 9.5 and 10.7 respectively. Some of the species having higher frequency of occurrence in the community were not eaten. 89.0 per cent of the gerbil food in this community comprised of grasses.

(c) *Cyperus arenarius—Digitaria adscendens—Pulicaria wightiana—Justicia vahlii* community —The plant community occurred on an inter-dune sandy plain.

The first two species in this community had 100 per cent frequency in the transects, and the latter two had 83.3 per cent frequency. *Eragrostis cilianensis* and *Tragus biflorus* had a frequency of 66.6 per cent. In this community *Cenchrus ciliaris* formed 25.5 per cent and *Eragrostis cilianensis* 8.5 per cent of the gerbil food in spite of being only 4 and 0.5 per cent respectively in nature (Table 21), indicating that they are most preferred by the desert gerbils. *Cyperus arenarius* and *Digitaria adscendens* have a higher occurrence (24.5 and 14.0 per cent respectively) in nature as compared to that in the gerbil food (17.0 and 8.5 per cent respectively) and both the species are rated as 'less preferred'. *Pulicaria wightiana* and *Justicia vahlii,* though predominantly occurring in nature, did not at all occur as gerbil food. In this community, grasses formed 73.1 per cent of the gerbil food.

(d) *Pulicaria wightiana—Justicia vahlii—Polycarpaea corymbosa—Sporobolus helvolus* community—This community was situated on the flat top of a sand dune. All the four species forming the community had 100 per cent frequency in the transects. *Aristida adscendionis* and *Convolvulus microphyllus* had 75

Table 20. Per cent occurrence of unconsumed plant species near gerbil burrow openings and in nature, and their palatability classes in the plant community (Prakash, 1969)

Plant species	Per cent occurrence: Unconsumed plant species neer burrow opening	Per cent occurrence: in nature	Palatability classes
Digitaria adscendens	21.3	17.3	less preferred
Cenchrus ciliaris	18.6	1.8	most preferred
Brachiaria ramosa	8.0	9.5	less preferred
Eragrostis ciliaris	8.0	6.5	preferred
Aristida adscensionis	8.0	6.0	preferred
Dactyloctenium aegyptium	8.0	3.5	most preferred
Eragrostis cilianensis	6 6	1.8	most preferred
Cenchrus biflorus	5.3	0.6	most preferred
Tribulus terrestris	2.6	12.0	not preferred
Tragus biflorus	2.6	3.0	less preferred
Glinus hirta	2.6	1.8	preferred
Cucumis callosus	2.6	0.6	most preferred
Perotis hordeiformis	1.3	10.7	not preferred
Cyperus arenarius	1.3	3.0	not preferred
Boerhavia diffusa	1.3	0.6	most preferred
Cenchrus setigerus	1.3	0.6	most preferred

Table 21. Per cent occurrence of unconsumed plant species near gerbil burrow openings and in nature, and their palatability classes in the plant community (Prakash, 1969)

Plant species	Per cent occurrence		Palatability classes
	Unconsumed plant species near burrow openings	in nature	
Cenchrus ciliaris	25.5	4.0	most preferred
Cyperus arenarius	17.0	24.5	less preferred
Digitaria adscendens	8.5	14.0	less preferred
Aristida adcensionis	8.5	2.0	most preferred
Eragrostis cilianensis	8.5	0.5	most preferred
Cynodon dactylon	6.3	2.0	most preferred
Polycarpoea corymbosa	6.3	1.5	most preferred
Eragrostis ciliaris	4.2	4.5	less preferred
Tragus biflorus	4.2	4.5	less preferred
Eleusine compressa	4.2	0.5	most preferred
Trichodesma indica	2.1	2.5	less preferred

Table 22. Per cent occurrence of unconsumed plant species near the burrow openings and in nature, and their palatability classes in the plant community (Prakash, 1969)

Plant species	Per cent occurrence		Palatability classes
	Unconsumed plant species near burrow openings	in nature	
Brachiaria ramosa	22.7	4.0	most preferred
Perotis hordeiformis	13.5	4.0	most preferred
Cenchrus biflorus	9.0	4.0	most preferred
Aristida adscensionis	9.0	3.2	most preferred
Convolvulus microphyllus	9.0	2.4	most preferred
Sporobolus helvolus	4.5	17.6	not preferred
Fimbristylus barbata	4.5	3.2	preferred
Digitaria adscendens	4.5	0.8	most preferred
Boerhavia diffusa	4.5	0.8	most preferred
Glimus hirta	4.5	0.8	most preferred
Tragus biflorus	4.5	0.8	most preferred

per cent frequency. All the dominant species of the community were absent from the gerbil food except a low (4.5 per cent) occurrence of *Sporobolus helvolus* as against 17.5 per cent (Table 22) incidence in nature which shows that the species was not preferred by gerbils. *Cenchrus ciliaris*, the occurrence of which is maximum in the gerbil food, was absent in this community and the desert gerbil showed lesser selectivity in preferring various food species when compared to other communities in which it was present. *Perotis hordeiformis*, rated not preferred in community (b) was rated as most preferred. Moreover, all the species except *Sporobolus helvolus* and *Fimbristylis barbata* were rated as most preferred. It appears, therefore, that in the presence of the choicest species, the rodents do not show selectivity in choosing their food. In this community 89.0 per cent food comprised of various species of grasses.

Palatability index of various plant species—Table 23 shows that out of the seven species which occurred as food item in more than two communities, the first six belong to family Poaceae which indicates that the Indian desert gerbil, *Meriones hurrianae, mainly* feeds on grasses. *Cyperus arenarius* (Cyperaceae) was the only non-grass species to occur in this hierarchy of preference but it is rated lowest as compared to other six grasses. All these grasses are palatable to livestock.

Field observations with binoculars—Observations with binoculars revealed that the gerbils fed mostly on shoots, leaves and inflorescence of plants (Prakash, 1969). In an earlier study (Prakash, 1962) on the examination of stomach contents it was found that during monsoon season the occurrence of these plant parts increased whereas in other seasons, seeds formed their main food.

Table 23. Palatability index of unconsumed plant species occurring in more than two communities, as rated by desert gerbils (Prakash, 1969)

Plant species	Family	No. of communities in which occurred	Palatability index
Cenchrus ciliaris	Poaceae	3	4.5
Aristida adscensionis	Poaceae	4	3.7
Eragrostis ciliaris	Poaceae	4	3.0
Digitaria adscendens	Poaceae	4	2.7
Brachiaria ramosa	Poaceae	3	2.7
Tragus biflorus	Poaceae	3	2.6
Cyperus arenarius	Cyperaceae	3	2.3

The following plant species were observed being consumed by the gerbil.

Family POACEAE

1. *Cenchrus ciliaris*
2. *Cenchrus setigerus*
3. *Cenchrus biflorus*
4. *Aristida adscensionis*
5. *Digitaria adscendens*
6. *Eleusine compressa*
7. *Cynodon dactylon*
8. *Eragrostis ciliaris*
9. *Eragrostis cilianensis*
10. *Dactyloctenium aegyptium*
11. *Brachiaria ramosa*
12. *Perotis hordeiformis*
13. *Tragus biflorus*

Family CARYOPHYLLACEAE

14. *Polycarpaea corymbosa*

Family CYPERACEAE

15. *Cyperus arenarius*

Family ZYGOPHYLLACEAE

16. *Tribulus terrestris*

Family MOLLUGINACEAE

17. *Glinus hirta*

Family CUCURBITACEAE

18. *Cucumis callosus*
19. *Citrullus colocynthis*

Family NYCTAGINACEAE

20. *Boerhaavia diffusa*

Family CONVOLVULACEAE

21. *Convolvulus microphyllus*

Out of 21 species eaten by the Desert gerbil, 13 were grass species and most of the plants observed being fed on by the gerbil are those which were found unconsumed near gerbil burrow openings Thus, besides consumption there is also perhaps a larger amount of destruction through the cut and unconsumed material.

Economic consideration—In the desert tract, where the study was conducted, the density of Desert gerbil was estimated to be 477 per hectare. Considering that a gerbil consumes about 6 cm feed per day (Prakash and Kumbkarni, 1962), their annual requirement will be 1044 kg/hectare; assuming that their number will be maintained at this level all the year round.

The figures of the estimated forage production in this tract during 1963-64 and 1964-65 are summarised in Table 24 (Ahuja, Personal communication). Comparing the gerbil depredation and forage production figures, it will be observed that hardly any fodder will be left for livestock, particularly when the estimate of the gerbil consumption does not include the destruction they do merely by cutting the grasses to reach the inflorescence. The rodents also destroy the vegetation by damaging their roots by tunnelling and expose the loose soilexcavated from these tunnels to wind, thus affecting grass growth. All these factors in their turn affect the establishment of good pastures for proper livestock industry which largely depends on these pastures. It is, therefore, essential that control operations are to be visualised while planning improvements to rangelands (Prakash, 1969).

Losses

At harvest, the *bajra* (*Pennisetum typhoides*) cobs from the field are heaped in the backyards of huts in villages of the desert region. The gerbils follow the cobs, dig tunnels under them and feed upon the *bajra* grains leaving the cob near the burrow openings. In one such village, some 40 gerbils were observed in a 15 m x 40 m area—a very high density of gerbil population.

Grasses and fodder crops—Whenever seeds of *Cenchrus setigerus, C. ciliaris* and *L. sindicus* are sown in grasslands to improve the fodder quality for better animal production, rodents dig them up and feed on them almost to the roots of the fodder. The intake of grass seeds by *M. hurrianae* is much greater than that of the other desert rodents (Prakash *et al.*, 1967). In the monsoon season, the rodents prefer to feed upon the unripe inflorescence of grasses; unable to reach them, they gnaw the base of the plant. Field rodents devastated some 40 acres of *L. sindicus* and 27 acres of *C. ciliaris*. *C. setigerus* and *L. sindicus* in an experimental pasture at Bikaner. Other damages to natural grasses have already been described.

Soil conservation—The desert gerbil by its burrowing habit threatens conservation work. Its burrows are extensive and have no fixed pattern (Prakash, 1962; Fitzwater and Prakash, 1969; Barnett and Prakash, 1975). The burrow openings are scattered everywhere and as many as 14,000 have been counted in a plot of 100 m x 100 m. By tunnelling, it excavates fixed soil forming small mounds (about 1 kg) near each burrow opening. At this rate, gerbils unearth about 17,000 kg soil per hectare; the loose soil is blown away by strong winds increasing the areas of sandy wastes and barren land. In Shekhawati region, *Meriones hurrianae* excavated 61,500 kg/day/km^2 soil in cultivated field and 10,43,800 kg/day/km^2 in uncultivated field (Sharma and

Table 24. Forage production (air dried) per hectare at Maulasar (Prakash, 1969)

Forage species		Forage production (air dried) per hectare, kg. 1963-64	1964-65
1. Edible grasses :	High perennials (*Cenchrus* spp.	332	196
	Low perennials (*Eleusine compressa*, *Cynodon dactylon*, etc.)	31	8
	Cyperus spp.	25	8
	Annuals (*Aristidd* spp. *Cenchrus biflorus*, *Digitaria adscendens*, *Tragus biflorus*, etc.)	822	307
Total edible species		1210	519
2. Non-edible species		159	315
Total forage production		1369	834

Joshi, 1975). This study further highlights the severity of soil erosion by rodents.

Food in Laboratory Conditions

Feeding behaviour

Meriones hurrianae is essentially a diurnal species. In nature, it comes out of its burrow for feeding just after dawn and retires after a few hours before it is too warm. It again comes out at about 6 p.m. and retires at 7.30 p.m. In w nter, however, it is out of its burrow throughout the day but not during the mornings and evenings when it is quite cold. Due to human intervention in the laboratory the gerbils adjusted their feeding times to avoid the working hours. 62% of the total daily intake was consumed from 6 a.m. to 10 a.m. and the rest between 5 p.m. and 7 p.m. This was observed all the year round (Prakash and Kumbkarni, 1962).

Total daily intake (TDI)

The gerbils did not accept any food when they were freshly brought under captivity, although the size of the cage was large, viz. 225 x 75 x 75 cm., and not more than six gerbils were kept in one cage. After 3-4 days the rodents started eating meagre amounts and about 10 days after their capture their TDI became stationary. Table 25 shows the average TDI of various grains and pulses as consumed in 24 hours per gerbil. During this series of experiments only one food item was tried at a time with a group of 6 to 12 gerbils. Water was provided for drinking during every trial. It is observed that wheat flour is most preferred. Table 25 also shows the calorific values of the

Table 25. Average Total Daily Intake of Gerbils and its calorific value* (Prakash and Kumbakarni, 1962)

Food	TDI (gm)	TDI as % of body wt.	% Moisture	Calorific value of TDI
Wheat flour	7 04±0.38	11.3	12.2	24.71
Sorghum, *Sorghum vulgare*	6. 5±0.28	10.5	11.9	22.11
Millet, *pennisetum typhoideum*	5. 5±0.26	8.9	12.4	19.8
Moong (green gram), *Phaseolus radiatus*	5. 5±0.41	8 06	10.4	16.7
Whole wheat, *Triticum aestivum*	4. 0±0.15	6.4	12.8	13.92
Bengal gram, *Cicer arietinum*	4. 0±0.56	6.4	9.8	14.0
Maize, *Zea mays*	3. 8±0.41	6.1	14.9	13.0
Moth, Phaseolus aconitifolius	3. 6±0.67	5.8	—	—
Barley, *Hordeum vulgare*	3. 4±0.35	5.4	12.5	13.3
Guar, Cyamopsis tetragonoloba	1.98±0.30	3.2	—	—

*Aftér Aykroyd *et. al.*, (1960)

various TDI. It is calculated that with food giving 12-15 calories of energy a day, one gerbille* of 45-55 g weight group can maintain its body weight.

Seed Consumption

It was observed earlier that in nature the gerbilles consume seeds upto 60% in January, and thereafter the percentage decreases to 10 in July; it then increases to 60 in December (Prakash, 1962). Seeds of the following plant species could be identified from the stomach contents of gerbils which were collected and analysed all the year round: *Cenchrus* spp., *Boerhaavia diffusa, Tephrosia purpurea, Crotalaria burhia, Farsetia jacquemontii, Capparis decidua, Zizyphus* spp., *Cynodon dactylon, Trianthema portulacastrum, Cucumis trigonus, Colocynthis vulgaris, Prosopis juliflora,* and *Eragrostis ciliaris.* It was, therefore, considered that the of plants found in the gerbil habitat form their main food. This was confirmed by the Silviculture Section of the Institute, more than 50% of the sown seeds being destroyed by the gerbils. Therefore, seeds of plants found around gerbil burrows and those of afforestation and grassland importance were given to them to study the seed consumption in 24 hours. Trials were conducted with groups of animals after their adaptation to captivity. In some groups water was provided, and in others the gerbils were maintained without water, but there was no appreciable difference in the consumption. The data in Table 26 show the average amount of

Table 26. Average seed consumption per gerbil during 24 hours (Prakash and Kumbakarni, 1962)

Seeds of	Consumption in 24 hours (g/per gerbille)
Panicum antidotale	3.25 ± 0.79
Dichanthium annulatum	2.5 ± 0.76
Lasiurus hirsutus	2.1 ± 0.48
Cenchrus setigerus	0.85 ± 0.25
Cenchrus ciliaris	2.1 ± 0.41
Zizyphus nummularia	1.75 ± 0.65
Tecomella undulata	1.50 ± 0.33
Prosopis juliflora	1.21 ± 0.36
Albizzia lebbek	1.20 ± 0.40
Aerva tomentosa	0.66 ± 0.17
Acacia senegal	0.40 ± 0.05
Acacia arabica	0.37 ± 0.16

Significance at 5% level. Items 2-12 $P < 0.001$ with millet and sorghum control.

Item 1 $P < 0.01$ with millet control.

Item 1 $P < 0.001$ with sorghum control.

* The old spelling of gerbil was gerbille

seeds consumed during 24 hours per gerbil. When compared to millet (*Pennisetum typhoideum*) and sorghum (*Sorghum* sp.) controls, the TDI of seeds is significantly very low. Amongst the grass seeds, those of *Panicum antidotale* were consumed in larger quantities. Next higher consumption was of *Dichanthium annulatum*, *Lasiurus hirsutus* and *Cenchrus setigerus* seeds. Amongst other plant seeds those of *Zizyphus nummularia* were consumed at the average rate of 1.75 ± 0.65 gm. during 24 hours per gerbille. Seeds of Acacia spp. were least consumed (Prakash and Kumbkarni, 1962).

Seed Preference

There are many factors governing the seed consumption when seeds of only one plant species are provided to gerbilles for preference trials. The seeds may have spines, they may be very hard, or when there is only one food for the starving gerbils they may be forced to feed upon that particular seed as in the previous trials, the amount of seed consumption may not be indicative of their true seed preference. Seeds of various plants were therefore, given to gerbils in combinations. The gerbil was placed in a small cage (75 x 75 x 75 cm.) and the experimental food was given in equal quantities in two petri dishes of the same size. To minimise the factor of availability during every trial the positions of the samples were rotated. Combinations of two and three seeds were tried. The preference was denoted by the amount of seeds consumed during 24 hours. The results are expressed in Tables 27 and 28, following the method of Cott (1951) and Prakash (1957). The arrows point toward the preferred species. By comparing data in Tables 25, 26, 27 & 28 it will be observed that the preference and choice of gerbil is quite consistent.

Body weight in relation to feeding without water

Meriones practically do not get drinking water in nature. In captivity they readily accept water and on an average a gerbil consumes 2.78 ± 0.18 ml water during 24 hours when being fed on air-dried seeds. To ascertain the influence of

Table 27. Preference of grass seeds (Prakash and Kumbakarni, 1962)

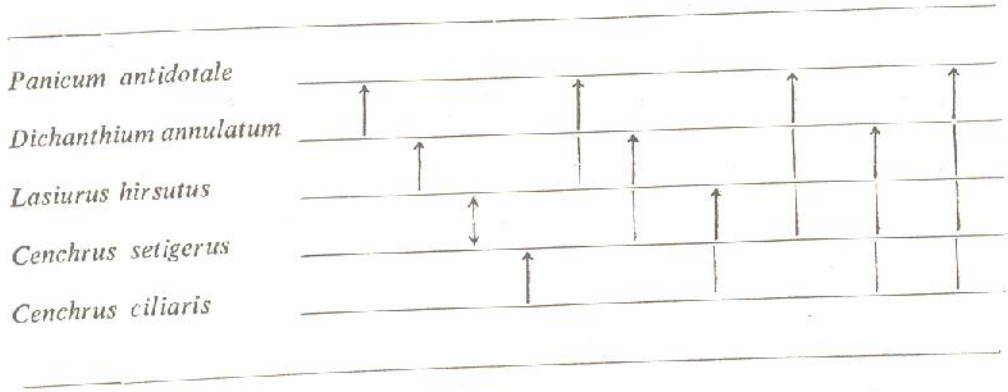
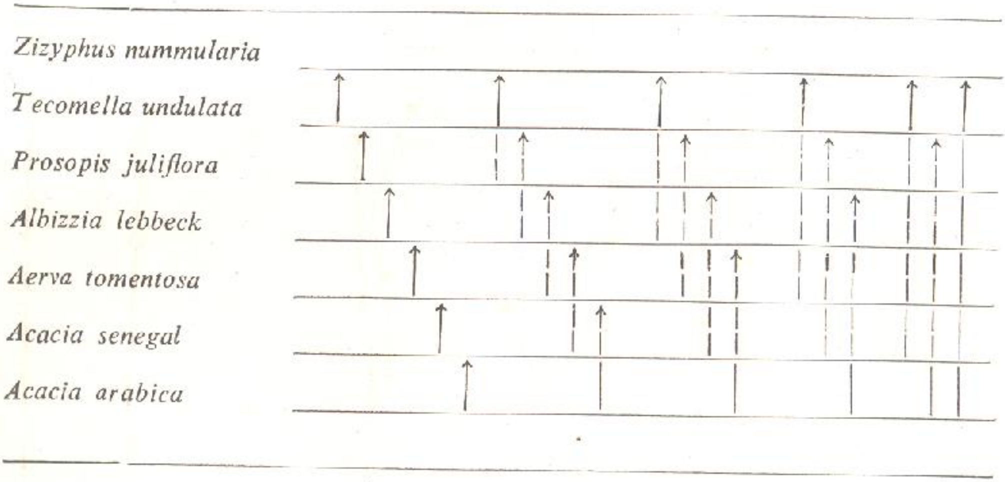


Table 28. Preference of other plant seeds (Prakash and Kumbakarni, 962)



water consumption on body weight, wheat was provided to gerbils with and without water. The experiment lasted for about a month. The group of gerbils being fed without water lost weight considerably but the other group maintained body weight (Fig. 6). These results from experiments in captivity are particularly interesting since gerbils not only maintain but add to their body weight when they do not get any water in nature.

Body weight in relation to seed food

The graph (Fig. 6) indicates two curves, one showing the body weight losses when a group of gerbils was fed on grass seeds and the second shows the body weight on other seeds. Till the 21st day while feeding on grass seeds, the curve declines steeply whereafter there is an increase in body weight, but when the gerbils were fed on other seeds the body weight fell so much in 12-14 days that the gerbils started dying and strong cannibalistic tendencies were induced due to starvation. After this critical period the body weight was maintained by the remaining gerbils of the group.

Bait preferences

Every bait preference test was conducted with 10 gerbils, each lodged in individual laboratory cage. Three baits, selected from 10 candidate baits, with the aid of random number tables, were exposed to every gerbil for a period of six days, following our earlier work. The consumption of each bait was measured daily and replaced with a new series of baits on the following day. Average daily intake (ADI) of each bait was calculated at the end of each test, after transforming the absolute consumption values to g/100 g body weight of individual rat. Vegetable oils, salt and sugar were added to cereals as additives. During all the tests were conducted as per the following scheme.

Test I: Air dried whole grains–Test II: Cracked grains–Test III: Whole

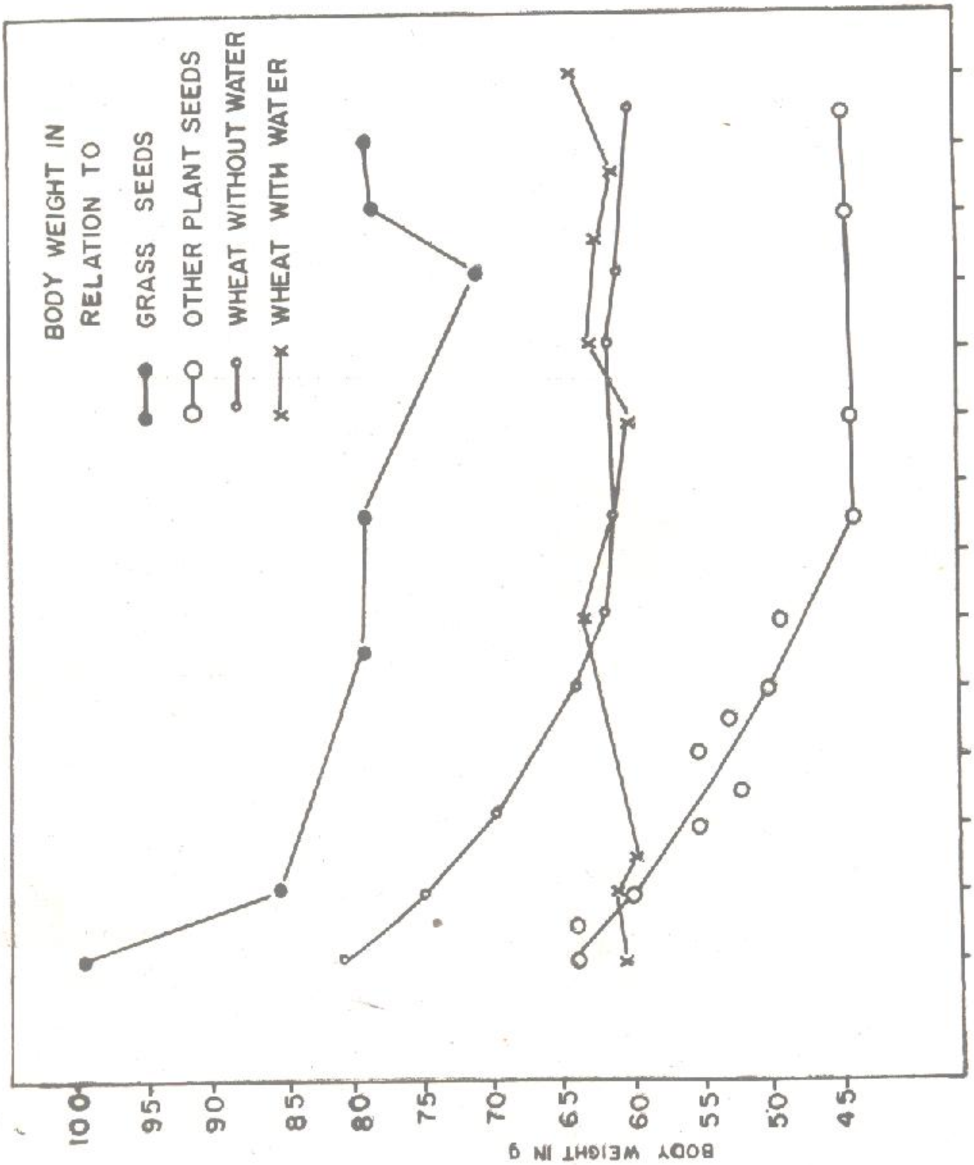


Fig. 6. Body weight in relation to various feeds

Damage by desert gerbil to standing wheat crop (above) and to harvested bajra (below)

Table 29. Relative consumption of best ranking food items in each test (Adapted from Prakash *et al.*, 1978)

Baits (best from each test)	ADI (g) (Mean ± S.E.)	Per cent	Rank
Bajra, whole	2.32 ± 0.33	7.15	9
Bajra. cracked	3.26 ± 0.63	10.04	4
Chana, flour	2.01 ± 0.44	6.19	10
Jowar, + 2% arachis oil	2.52 ± 0.50	7.76	8
Moth, + 2% sesame oil + 1% sugar	2.88 ± 0.55	8.87	6
Wheat, cracked	3.25 ± 0.52	10.01	5
Wheat, roasted	2.74 ± 0.31	8.44	7
Wheat, flour	5.08 ± 0.75	15.65	1
Wheat flour + 10% sesame oil	4.93 ± 0.79	15.19	2
Wheat flour + 10% arachis oil + 1% sugar	3.47 ± 0.54	10.69	3

grains v/s cracked grains–Test IV: Whole grains v/s Roasted grains–Test V: Whole grains + 2% vegetable oils–Test VI: Whole grains + 2% oil + 1% salt or sugar–Test VII: Flours–Test VIII: Whole grains v/s flours–Test IX: Flours + 10% vegetable oil–Test X Flours + oil + 1% salt or sugar–Test XI: Best ranking food item from each test.

The average body weight (mean ± S.E.) of experimental animals was 69.65 ± 3.35 g.

In the eleven tests, *bajra* fared as the top ranking bait in four tests, wheat with various combinations in three, and *chana* flour, *jowar* + arachis oil and *moth*+sesame oil+sugar were preferred in rest of the tests. The relative consumption of best ranking food items in each test are shown in Table 29.

It is observed from the results of these tests that the gerbils, however, readily accept a change in food. It is quite expected since the desert gerbil is fairly well adapted to such a behavioural switch over in its food habits synchronising with its availability changing with seasons which are very pronounced in the desert environment. This is fairly helpful for a rodent control operator since the bait and poison are to be changed for a subsequent operation this plastic adaptability of gerbil can be made use of. Wheat is not grown in the desert region on a large scale. Hence it is not freely available with the rural population and *bajra* is the main crop of the region in which the desert gerbil occurs as the predominant rodent. Considering the availability of *bajra* (Pearl millet) with the farmer, cracked *bajra* is recommended as the bait for mixing poison for field control campaigns.

Test I, II, III and VII and VIII pertain to the same candidate baits but in different forms or particle size: whole grains, cracked and flour Tables 30 & 31. A comparison of the data do not suggest a definite conclusion. Cracked *bajra, barley, moong* and *moth* were consumed more than their other forms, whereas ADI of flours of *chana, guar, jowar, maize,* and *wheat* were more than those of the two other forms. In Test III, the gerbils exhibited a clear choice for cracked grains. But in Test VIII they preferred whole grains in comparison to the flours. With this fluctuating choice apparent from the experiments, it appears that desert gerbils are not consistent for choice of food according to its particle size (Prakash *et al.,* 1978). As already explained that *M. hurrianae* are adapted to survive in the desert on such a wide variety of dietary items, that a clear preference is also not expected.

Additives—Two types of additives were exposed to the desert gerbils for assessing their role in enhancing the bait consumption: vegetable oils, salt and sugar (Test V, VI, IX and X). A comparison of ADI of whole grains (Test I) and that with one of the two oils (Test V) reveals that the addition of oils reduced their consumption (Table 32) However, out of the two oils, sesame was preferred. With flours (Test VII and IX), however, the arachis oil mixed flours were preferred, though the difference between the ADI of the two was not statistically significant. Likewise the results of Tests VI and X indicate that addition of salt or sugar had but very little effect on the bait consumption Table 33. Our experiments indicate that addition of vegetable oils, salt and sugar did not enhance the consumption of baits (Prakash *et al.,* 1978).

Table 30. Consumption (g/100 g body weight) of grains by *Meriones hurrianae* (Adapted from Prakash *et al.*, 1978)

Food items	Whole grains (Mean ± S.E.)	Cracked grains (Mean ± S.E.)	Flours (Mean ± S.E.)
Bajra	4.55 ± 0.42	5.39 ± 0.57	1.83 ± 0.31
Barley	1.91 ± 0.61	2.27 ± 0.44	1.91 ± 0.28
Chana	2.38 ± 0.47	1.28 ± 0.34	3.06 ± 0.51
Guar	0.41 ± 0.27	0.27 ± 0.33	1.00 ± 0.20
Jowar	0.98 ± 0.45	0.97 ± 0.21	1.55 ± 0.36
Maize	1.38 ± 0.36	1.10 ± 0.31	1.70 ± 0.27
Moong	1.71 ± 0.36	3.04 ± 0.58	2.21 ± 0.34
Moth	0.54 ± 0.16	3.14 ± 0.62	2.12 ± 0.38
Urd	3.13 ± 0.57	0.80 ± 0.21	1.44 ± 0.19
Wheat	0.51 ± 2.90	2.70 ± 0.50	2.71 ± 0.45

Table 31. Consumption (g/100 g body weight) of different forms of grains by *Meriones hurrianae* (Adapted from Prakash *et al.*, 1978)

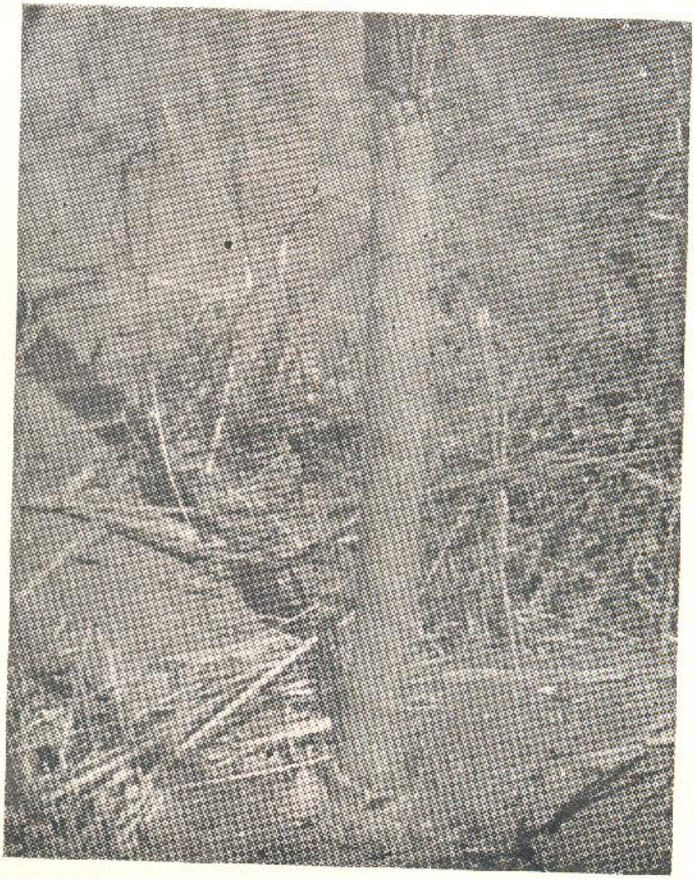
Food items	Whole v/s cracked grains		Whole v/s Roasted grains		Whole grain v/s Flour	
	Whole (Mean ± S.E.)	Cracked (Mean ± S.E.)	Whole (Mean ± S.E.)	Roasted (Mean ± S.E.)	Whole (Mean ± S.E.)	Flours (Mean ± S.E.)
Bajra	3.02 ± 0.45	3.53 ± 0.41	2.76 ± 0.30	1.42 ± 0.17	—	—
Barley	1.12 ± 0.22	1.70 ± 0.28	—	—	2.73 ± 0.30	2.31 ± 0.49
Chana	—	—	1.18 ± 0.30	1.32 ± 0.19	2.95 ± 0.64	2.54 ± 0.29
Jowar	—	—	1.66 ± 0.29	1.18 ± 0.15	—	—
Maize	—	—	1.48 ± 0.21	1.56 ± 0.23	—	—
Moong	1.52 ± 0.29	1.96 ± 0.30	—	—	3.25 ± 0.63	3.16 ± 0.31
Moth	1.66 ± 0.42	2.75 ± 0.45	—	—	2.66 ± 0.43	2.76 ± 0.35
Wheat	1.12 ± 0.22	3.12 ± 0.47	1.94 ± 0.25	1.69 ± 0.14	2.67 ± 0.23	4.50 ± 0.50

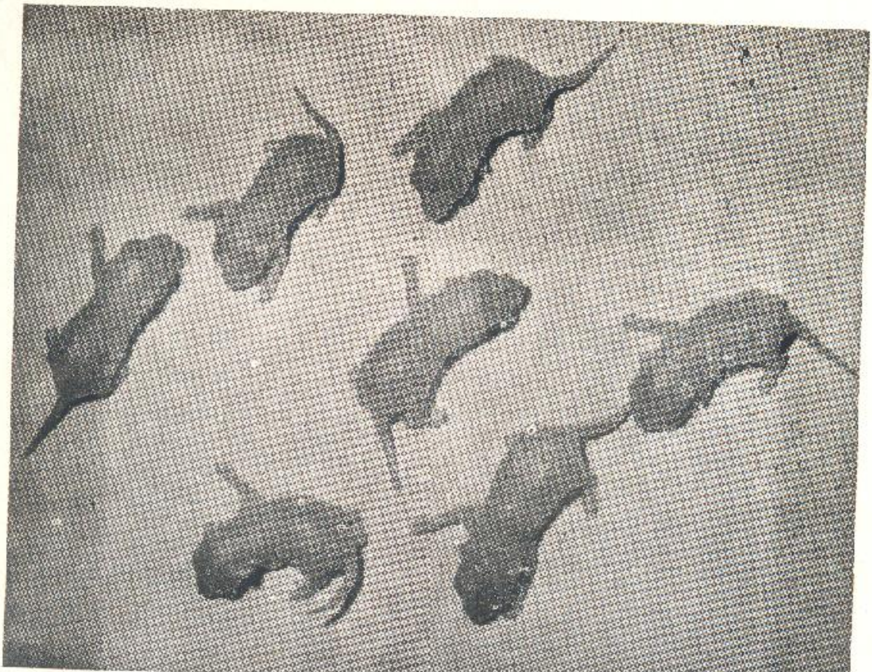
Table 32. Food consumption (g/100 g body weight; Mean ± S. .E) with oils by *Meriones hurrianae* (Adapted from Prakash *et al.*, 1978)

Food items	Whole grains + 2%		Flours + 10%	
	Arachis oil	Seeame oil	Arachis oil	Sesame oil
Bajra	1.30 ± 0.33	1.32 ± 0.29	—	—
Barley	1.39 ± 0.27	1.37 ± 0.24	2.91 ± 0.45	2.60 ± 0.39
Chana	—	—	3.41 ± 0.70	2.37 ± 0.26
Jowar	—	—	—	—
Moong	0.83 ± 0.27	0.94 ± 0.20	2.77 ± 0.86	2.59 ± 0.46
Moth	0.90 ± 0.20	1.34 ± 0.27	2.89 ± 0.53	2.18 ± 0.50
Wheat	1.00 ± 0.34	1.13 ± 0.30	3.81 ± 0.61	3.94 ± 0.66

Table 33. Food consumption (g/100 g body weight; Mean ± S. E.) with salt and sugar by *M. hurrianae* (Adapted from Prakash *et al.*, 1978)

Food items	Whole grains + 2%		Flours + 10% arachis oil	
	Salt	Sugar	Salt	Sugar
Bajra	0.65 ± 0.15	1.35 ± 0.33	—	—
Barley	—	—	1.63 ± 0.41	2.67 ± 0.65
Chana	—	—	2.25 ± 0.52	1.58 ± 0.24
Jowar	1.33 ± 0.44	1.02 ± 0.20	—	—
Moong	1.41 ± 0.29	1.17 ± 0.34	1.66 ± 0.26	2.77 ± 0.41
Moth	1.27 ± 0.33	2.26 ± 0.23	1.79 ± 0.33	2.88 ± 0.46
Wheat	1.95 ± 0.39	1.90 ± 0.26	2.37 ± 0.42	3.07 ± 0.43





Debarking of sapling makes the afforestation work difficult (above). Litter size of desert gerbil varies from 1 to 9.

REPRODUCTION

The desert gerbil did not litter in captivity though ample green food was provided during the peak breeding season. Most of the observations on reproduction activity are, therefore, on litters borne by pregnant females collected in the field. Usually deliveries occurred at night. A pad of cotton was invariably provided to the female which she utilised for placing the young one. In all, ninety-nine new-born young were handled in the laboratory. The rate of mortality due to the cannibalism of the mother was rather high. Some young died in an attempt to administer ether for taking measurements. After that measurements and weights were recorded on live specimens, and are analysed according to the procedures described by Brody (1945) and Butterworth (1961). Values are plotted in figure 9. Straight segments of the grap indicate periods when growth increments are constant percentages of previous sizes. From these straight sections, instantaneous growth rates were calculated according to the following formula:

$$k = \frac{\ln m_2 - \ln m_1}{t_2 - t_1}$$

where k is the instantaneous percentage rate of growth for the unit of time in which t_2 and t_1 are expressed, and $\ln m_2$ and $\ln m_1$ are natural logarithms of the measurements at t_2 and t_1 (Butterworth, 1961).

Oestrous cycle

The average period of oestrous cyc'e has been found to be 6.1/6.2 days (Kaul and Ramaswami, 1969; Ghosh and Taneja, 1968). Kaul and Ramaswami (1969) observed that the duration of proestrus varies from 0.5 to 3 days (average 1.4 days), oestrus 0.5 to 3 days (average 1.7 days), metoestrus 0.35 to 3 days (average 1.1 days) and dioestrus 0.5 to 10 days (average 1.9 days). In the vaginal smears of the gerbil three types of cells could be distinguished i.e., leucocytes, nucleated epithelial cells and cornified epithelial cells. During early proestrus, the smear consists of a large number of nucleated epithelial cells and a few leucocytes. Gradually the leucocytes disappear and the smear shows only nucleated epithelial cells. Large quantity of mucus is present at this stage. At the end of proestrus cornification of the nucleated epethelial cells sets in. Early oestrus is marked by cornification of majority of the ep'thelial cells. During mid oestrus only cornified epithelial cells are present in the smear, while at the end of oestrus desquamation of the vaginal epitheliam starts. Mucus is absent in the smear showing cornified cells. In the post oestrus or metoestrus period the smear consists of large number of nucleated epithelial cells. There is little mucus at this stage. During late metoestrus infiltration of leucocytes begins. As dioestrus approaches the number of the nucleated epithelial cells gradually lessens and the smear shows mainly leucocytes and few nucleated epithelial cells (Kaul and Ramaswami, 1969).

Mating Behaviour

Fitzwater and Prakash (1969) observed the mating behaviour of *M. hurrianae*. Before mating, the male and female 'nose' each other, usually the male approaching the female. Sometimes the male is repelled by kicking but at other times the female is receptive. The female assumes the lordosis position and allows the male to mount. On one occasion the female arched so much that the male was thrown off balance and fell to the side. Mating consists of multiple mounts in a series. In one mating observed between male No. 10 and female No. 32 the sequence was:

0823-0825 hrs. — 4 times
0830-0839 hrs. – 18 times
0842-0846 hrs. — 9 times

Total duration of mating = 23 minutes

Actual time of coitus = 15 minutes

Intervals between series of mountings = 3 and 5 minutes

Total number of mounts observed = 31 times

On other occasions the total duration of mating was observed to vary from 10 to 40 minutes while duration of actual coitus was between 5 to 10 minutes and mounting was repeated from 13 to 21 times. In most cases during the pause between series of mountings both partners started feeding. A few females even continued to feed while they were being served. Both the sexes at times licked their genitalia after coitus.

Several times male desert gerbils were observed during or after copulation sidling with hind legs spread out so that the scrotum was dragged on the ground. This type of 'perineal drag' is also shown by males of *Perognathus*, *Microdipodops* and *Dipodomys* while driving a female and when she does not assume the position of lordosis (Eisenberg, 1963/1975). It is interesting that a parallel behaviour has evolved in these rodents which are widely separated geographically.

Other desert gerbils in the vicinity of mating pairs do not take any interest in them. Only once a male, heavier than the mating one (No. 10) disturbed the action but was given a hot chase and driven away. Mating was resumed soon after.

Seasonal Incidence of Breeding

Females littered throughout the year (Table 34). It will be noticed that there are two peaks in the incidence of births: February and July. The gerbils pass the cold spell in December and January in a state of torpidity. As soon as this torpidity is over, sexual activity increases and hence the peak in births in February. The increased activity in July is attributed to the optimum conditions existing during the rainy season in the desert (Prakash, 1960). It was earlier observed that the gerbil litters only during August-October (Prakash, 1960, 1962). This observation

Table 34. Seasonal incidence of breeding in desert gerbil (Prakash, 1964b)

	Months											
	Jan.	Feb.	Mar.	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
Number of litters born	4	11	2	1	1	2	8	6	4	5	4	6
Total number of females collected	15	26	9	7	8	10	14	12	8	12	14	22

was based on the field collection of pregnant females during 1953-56. The collection of the gerbil in various months has, however, shown that they breed all the year round. However, Kaul and Ramaswami (1969) observed three peaks in the pregnancy rate, February to April, July and September to November at Jaipur.

It is observed that the reproduction of desert gerbil is influenced by the availability of green vegetation which is in turn influenced by the amount of precipitation (Prakash, 1975a). Breeding activity is also broadly correlated to the mean monthly day length. Its reproductive activity is low during winter when day length is shortest, apparently due to the ovarian refractoriness to photoperiods. It has also been revealed that during drought years the breeding potential of *Meriones hurrianae* is decreased considerably (Prakash, 1968). During 1968-69 (Drought year) rodent survey of the Indian desert, we also found a very low pregnancy rate in *Meriones hurrianae* (Prakash, 1971).

Gestation Period

The period of gestation in *Meriones hurrianae* is not correctly known. A female littered on the night of February 11. The next morning the male gerbil was removed from the cage. Mother and the young remained in the cage. The female again littered on the night of March 13. It appears that the male served the parturient mother in the morning of February 12. The period of gestation was 30 days. In another case a female gerbille was introduced to a male and they mated the same afternoon. The delivery occurred after 28 days. In two more instances the period of gestation was found to be 28 and 29 days.

Parturition

Parturition was observed only in one female. In the laboratory, she delivered two young in the early morning which was not observed. At 10 a.m. the mother was noticed to be extremely uneasy and at 11 a.m. she delivered one whitish, dead young. The head was presented first and the entire body was, thereafter, almost dropped. Just before delivery a whitish fluid oozed out but there was no discharge of blood. During delivery the mother lay flat on her belly with her hindquarters raised slightly above the floor of the cage. Her eyes were closed and hind region was quivering. Only with great difficulty could she walk. At 12.30 p.m. the mother delivered another young, head first. This time the body of the mother shook violently and she kicked her hind limbs while lying flat on the floor of the cage. The mother did not appear to pay attention to the young which lay half curled, on its back, moving its limbs in the air. Twenty-five minutes later she got up and licked the young one, collected it, and carried it to the cotton pad.

Post partum Conception

The female gerbil experiences heat period shortly after parturition and the implantation of blastocysts may occur after the lactation period (delayed implantation) (Kaul and Ramaswami, 1969).

Lactation Period

Average duration of lactation was found to be 30 days.

Litter Size

The litter size varies from 1 to 9 (Table 35), but is commonly three or four. Of the 23 litters born in the laboratory, the litter size was: 7 each of 3 and 4 young, 3 cases of 5 young, 2 cases each of 6 and 7, and one each of 1 and 9 young. It is natural to expect that the size of the young will be smaller in a large litter, but the data in Table 35 reveal that the average size of the young in litter of 9 was the biggest. The data also show the average linear measurements and weights of the new-born ones and their standard error according to various sizes of the litters. The averages of the ninety-nine young are: head and body, 40.2±0.60 mm; tail, 12.8±1.21 mm, hind foot 7.0± 0.42 mm, and weight 4.1±0.21 gm. Kaul and Ramaswami (1969) also observed at Jaipur the average litter size to be 4 (range 2 to 7).

New Born Young

At birth the young is hairless except for the 3-4 mm long vibrissae. The body is pink in colour. Eyes are closed, and appear as dark spots. The external auditory meatus is closed and the pinna is folded. The claws are whitish, soft and 2 mm long. The nipples were not visible in either sex. The sexes could not be differentiated. Young were unable to walk when a few hours old but could sway their limbs. They started squeaking within 4-6 hours of birth. They also opened their mouth and tried to grasp anything which touched their lips. Suckling started 3 to 6 hours after delivery.

Post-Natal Development and Behaviour of Young

First week—From the third day the dorsum of the young started darkening, beginning as a mid-dorsal line which gradually broadened and extended on the lateral sides. The unfolding of the pinna started from the 4th and 5th day after birth. The incisors could be felt below the gums. The vibrissae grew to 12-15 mm. The claws elongated but without pigmentation. The young one could crawl but was unable to support its body on its limbs.

Second week—Short, fine pelage appeared on the dorsum of the young, and by the end of the week extended to the flanks. A thin pencil of hairs appeared at the tip of the tail. The young gave a general impression of sepia colour. The vibrissae measured 30 mm and their tips became black. Plantar pads appeared on the hind foot but were feeble on the fore paw. The claws darkened. The eyes were still closed but at the end of the week a groove appeared at the centre, separating the lids. Incisors appeared in the jaws. Suckling continued.

Third week—Hair cover became complete and the pencil of hairs at the tip of the tail became darker. The vibrissae attained a length of 36-40 mm. The external auditory meatus opened. The upper incisors measured 1.5 and the lower 5.5 mm. The plantar pads of the hind limbs developed fully but those on the fore paws were still growing. The eyes opened after 15 to 16 days. Suckling ceased from 18 to 20 days. These two periods were observed in 8 and 6 cases only. The young could walk and chased the mother.

Table 35. Linear measurements and weights of the new-born in various litter sizes of desert gerbil (Prakash, 1964)

Size of litter		1	3	4	5	6	7	9
Total number of young measured		1	20	28	15	12	14	9
Head and Body	mm	40.0	39.1 ± 0.31	40.7 ± 0.83	40.6 ± 0.94	38.8 ± 0.23	39.4 ± 0.21	43.3 ± 0.25
Tail	mm	12.0	12.3 ± 0.76	12.1 ±0.43	11.0 ± 0.37	10.5 ± 0.11	11.5 ± 0.19	20.00
Hind foot	mm	8.0	7.6 ± 0.22	8.7 ± 0.37	7.0	6.9 ± 0.03	7.25 ± 0.13	10.00
Weight	g	4.2	4.4 ± 0.31	4.2 ± 0.28	3.04 ± 0.18	4.06 ± 0.13	4.02 ± 0.02	4.8 ± 0.09

Fourth week—Fur on the young developed fully. The white incisors, now 4 mm (upper jaw) and 8.5 mm (lower jaw), became paler. The pads of the fore feet also developed fully. The claws darkened completely. The external genitalia of either sex became distinguishable. The young were able to run and started thumping the ground with the hind foot as the sign of danger.

Subsequent growth—It will be observed further from the data in Table 36 that the rate of growth is very high in the first four weeks. 81.5 per cent growth of the ear and 80.9 per cent of the hind feet is attained in this period. 78 per cent head and body and 97 per cent tail growth is attained by the eighth week, whereas the ear and hind feet attain maximum dimensions by the sixth and eighth week respectively. Increase in body weight is gradual and 92.3 of the total is gained by the thirteenth week (Fig. 7).

Care of the Young and Cannibalism

Parturient mothers took about 25 to 30 minutes after delivery for taking care of the new-born young. Lactation started after 3 to 6 hours. Mothers were usually docile when their young were removed for measurements; they were not aggressive to their young when they were put back. Contrary to this, Fitch (1957) observed that the mother Prairie Vole, *Microtus ochrogaster*, attacked her young viciously and killed them within a few seconds, as soon as they were put back. When disturbed, the gerbil mother usually picks up its young ones and huddles them in a corner or under the cotton pad and starts suck'ing them. Muthana (1975) observed a fight between mother gerbil and a snake, *Coluber* sp. for rescuing the young from its mouth.

During the height of the breeding period, cannibalistic tendencies in the mother towards the new-born and of males towards the young were noticed and may be an important factor in the population dynamics of this species.

Table 36. Showing the per cent growth of the new born desert gerbil (Prakash, 1964b)

	Per cent growth in					
	first 4 weeks	next 4 weeks	next 5 weeks	next 4 weeks	next 4 weeks	next 4 weeks
Head and body	48.6	29.4	9.3	12.7	—	—
Tail	58.4	38.6	1.8	1.2	—	—
Ear	81.5	18.5 (6th week)	—	—	—	—
Hind foot	80.9	17.2	1.9	—	—	—
Weight	21-9	36.9	33.5	—	2.1	5.6

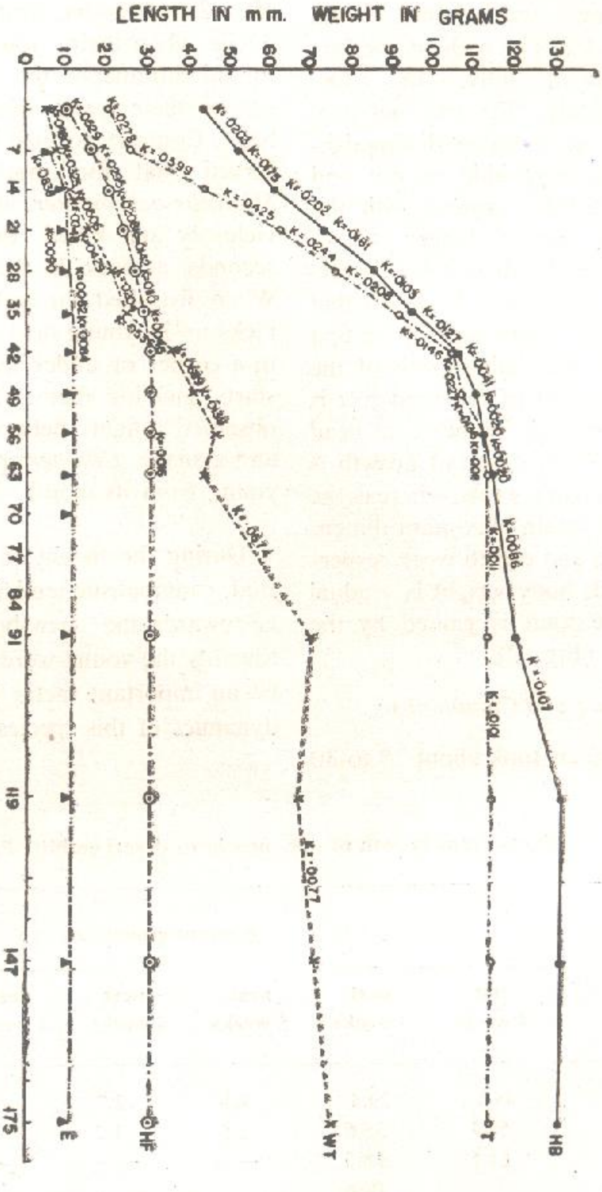


Fig. 7. Post-natal development of the Indian desert gerbil, *Meriones hurrianae.*

THE VENTRAL MARKING GLAND

Many mammals possess specialised glands and their secretions contain pheromones which the animals use for chemical communication. Though Dominic (1974) has carried out excellent work on the effect of pheromones present in the urine on mammalian fertility with reference to house mouse, very little work has been done in India on the role of secretion of mid-ventral scent marking gland. We have discovered this gland in three species (*Tatera indica indica, Meriones hurrianae* and *Rattus meltada pallidior*). In *M hurrianae* it is present in both the sexes and in the other two species the gland is present only in male animals (Prakash and Kumari, 1978; Kumari *at al.*, 1979).

Topography and Shape of the Gland

The mid ventral scent marking gland in *Meriones hurrianae* is present in both the sexes (Fig 8). It is prominently situated on the lower side of the abdomen. Ovoid in shape, broader on the anterior side, it is dirty yellow in colour. In a number of females, however, it was observed to be more elongate in shape. It can be easily seen by pushing the overlying hair on the sides. The gland surface is not totally devoid of hair and is fairly glandular in appearance, more in males.

Size

The glandular pad is larger in all the measurements in males as compared to that in females (Table 37), the difference between sexes being highly significant. In subadult animals (upto 40 g, Prakash, 1971a) this difference is not significant

Table 37. Size of the mid-ventral marking gland in desert gerbil (Prakash & Kumari 1978)

Species	Sex	Number	Mean ± S. E.		
			Length (mm)	Breadth (mm)	Area (mm^2)
Meriones hurrianae	Male	21	21.17 ± 1.05	4.87 ± 0.35	109.32 ± 13.26
	Female	18	14.86 ± 0.73	2.72 ± 0.15	41.59 ± 3.70

but as the animals grow it increases significantly ($P<0.001$), the disparity being maximum in the body weight class 81-100 g ($P<0.001$), which roughly correspond to 8 to 12 months of age. It is interesting to observe that even in the old animals (above 100 g body weight class) the gland area is significantly ($P<0.001$) larger than the preceding weight group in male *M. hurrianae,* (Kumari *et al.*, 1979). These findings are also confirmed by our observations on glandular area present in the pad in both the sexes (41.25% in male and 20.08% in females).

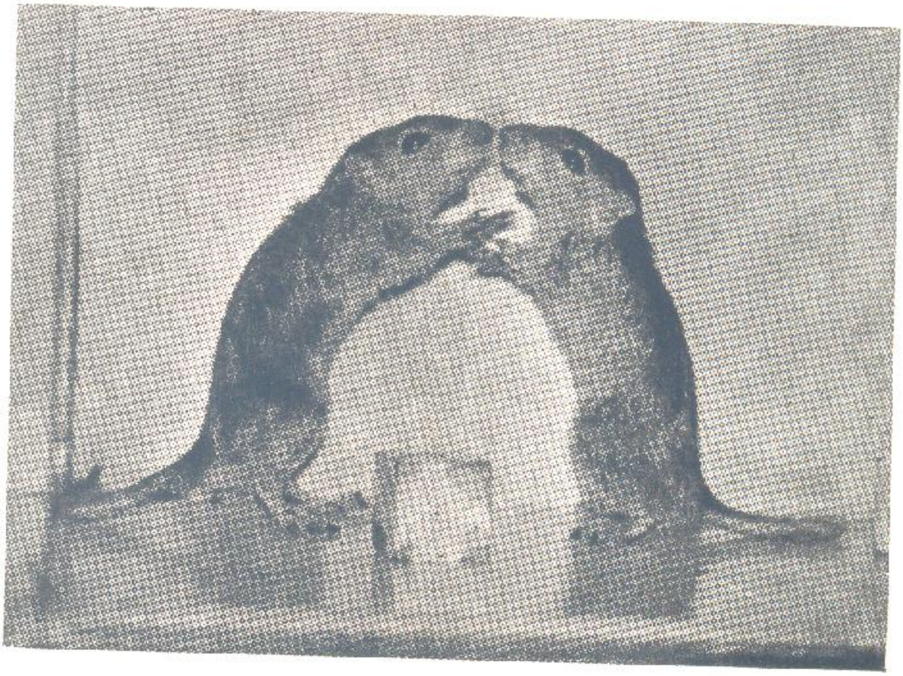
The mid ventral marking gland of *M. hurrianae* is similar to that of *M. unguiculatus* in respect of topography and shape, etc. but differs from it in the mode of growth. Glenn and Gray (1965) observed that in *M. unguiculatus* the average gland area in the male remained unaltered in the age groups 16-32 weeks and 32-50 weeks, but in females it increased considerably in these age groups. Our data reveal almost a reverse trend.

The gland measurements are positively and significantly correlated with body weight in both male and female merion gerbils (Kumari *et al.*, 1979).

Histology

The distinctive histological feature of the gland pad is its composite structure, composed of complexes of enlarged sebaceous acini of the typical holocrine type associated with the hair follicles. They are simple alveolar glands. Each gland is encapsulated in connective tissue. The secretory duct is wide and empties into the neck of the follicles. As the gland size of male *M. hurrianae* is twice in comparision to female, this is also compared with histological structure of female gland. The vertical section shows that the size of gland follicles in male is much larger than that of females, which explains that more secretions from male gland follicles than the females. Secretory mode is holocrine type and whole of alveolar gland cells become disintegrated at the time of discharge of the secretion and subsequently smaller alveoli also appear in immature stage. The gerbil gland is much simpler in structure in comparison to integumentary gland regions. Histological structure of Mongolian gerbil (*Meriones unguiculatus*) is similar to that of Indian desert gerbil (*Meriones hurrianae*) in having oval shape and wide secretory duct which empties into the neck of follicle (Kumari *et al.*, 1979).

A comparison of gland area and home range size revealed that the two do not correspond. Whereas, the gland size in male *M. hurrianae* is larger than that of female but the latter possess a bigger home range (154.7 ± 24.6 m^2 as against 88.7 ± 44.3 m^2 in male gerbils, Fitzwater and Prakash, 1969). Observations on gerbils in the field suggest that the most common use of mid ventral gland is for marking around the burrow entrance and the trails that gerbils use to move about to many burrows. The gerbils use regular pathways from one burrow to another opening on the surface and these pathways were regularly marked.



Two male *M. hurrianae* "boxing" (above). The ventral scent marking gland of male (left) and female (right) *M. hurrianae*.

ADAPTATIONS FOR DESERT SURVIVAL

The Indian desert gerbil is by far the most predominant rodent in the Indian desert, mainly because of its superiority to adapt to survive in a number of sub-habitats and formations, and by successfully adapting to withstand the vagaries of the arid environment. It does so by adjustments in its behaviour and physiology.

Behavioural Adaptations

Apart from the behavioural patterns discussed earlier several other behavioural aspects of the desert gerbil made them very much adapted to both desert environment and to their survival in nature when they are exposed to various toxic substances that can be encountered during the management operations by their major predator, the *Homo*. The understanding of these adaptations not only throws light on their survival capability, but also helps us in formulating an effective management programme of these desert gerbils.

Shift in the diel activity: The desertic environment is characterised by high temperatures during summer months and fairly cold during winter. The animals can dissipate this heat load by using more water at an excessive rate. Further, the merion gerbil being a small mammal, has larger relative surface area and needs more water for the dissipation of heat. Since water is scarcer in the desert, the gerbils restrict their activity to the cooler parts of the day. In summer, the merion gerbil comes out of its burrow just after dawn and retires after a few hours before it is too warm. It again ventures out after 6 p.m. and retires at 7.30-7.45 p.m. In winter, however, it is out of its burrow throughout the day but not during the mornings and evenings when the temperature is fairly cold (Prakash, 1962). Kashkarov and Kurbatov (1930) have also observed similar adjustment in the diel activity of another gerbil, *Rhombomys opimus* in the Central Kara Kum desert.

Fossorial mode of life: In addition to the shift in the diurnal activity, *M. hurrianae* is equipped with fossorial mode of life to avoid the external environmental havoc. As discussed earlier the merion gerbils inhabit extensive burrows (Ganguli and Kaul, 1962; Fitzwater and Prakash, 1969) and spend most of their time inside the burrow wherein uniform temperature and humidity conditions prevail all through the year (Prakash *et al.*, 1965). Consequently this diurnal desert gerbil is, in a way, not exposed to extremes of temperature stress. It has been observed that the gerbils visit burrows intermittently during the high temperature epoch for short durations probably to unload the hyperthermia developed due to exposure to outside environment (Fitzwater and Prakash, 1969). During the day the gerbil sometimes plugs the openings of the burrows to avoid the heat which causes loss of water. Further, when the animal respires, certain amount of moisture is given up, which is retained in the burrow helping in maintaining higher humidity. The urine passed in the tunnel also helps as a humidity regulating factor (Prakash, 1974). Besides, the desert gerbils continuously scrape the dried sand, shovels it out near the burrow entrance in a shape of mound for humidity regulation. This habit of scraping the sand has made the gerbil as a major soil erosion agent and one of the important factor in desertification in the Indian desert

Plasticity in food habits: The desert gerbil is omnivorous as discussed in the earlier chapter with changing food habits corresponding to its availability It feeds on seeds during winter, on rhizomes and stems during summer and on green leaves, flowers and stems during the monsoon. During summer this usually herbivorous rodent feeds on insects also, the bodies of which contain a high level of water which helps the gerbil to meet its own water requirement (Prakash, 1962). Thus by changing various dietary items during various seasons, *M. hurrianae* not only adapts to the availability of food but also tides over the intermittent periods of water scarcity.

Periodicity in breeding activity: Most of the mammals in the Indian desert breed during and soon after the rainy season and the ones which breed all the year round bear largest litters during this season and the figures of prevalence of pregnancy are also highest during the period of maximum precipitation (Prakash, 1960, 1971). In the desert environment three seasons (winter, summer, monsoon) are well pronounced, the first two represent the harsh epochs with respect to temperature, winter being too cold and summer too warm; as a consequence the breeding intensity of *M. hurrianae* is minimal during these two seasons (Prakash, 1964; Kaul and Ramaswami, 1969). The desert gerbil's adaptation to enhance the natality during and after monsoon period has several advantages in ensuring a higher level of survival rate of the young.

Abundant green nutritive food not only keeps the mother gerbils in good health in respect of milk production for suckling the larger litters but also enhances the chances of survival of young ones after weaning. During the drought years, when rainfall fails, the gerbils litter only during monsoon, and the reproductive activity during summer and winter totally vanishes (Prakash, 1968). During the 1968-69 (drought year) rodent survey (Prakash *et al.*, 1971a) of the entire desert, we found that only 12 per cent females were pregnant.

It is thus apparent that by adjusting the frequency of breeding to the changing environment during the year, and due to other desert adaptations, *M. hurrianae* is surviving in the Great Indian Desert as the most abundant mammal.

Physiological Adaptations

The Indian desert gerbil, *Meriones hurrianae*, encounters conditions induced by extremes of temperature, dry air, ge-

Table 38. Energetic parameters of *M. hurrianae*

A. *Below thermonential zone i.e. at 21 °C* (Ghosh *et al* 1979)

(i)	Metabolic rate (MR) ml O_2 / g /hr	1.71
	MR, percentage of the predicted value	130
(ii)	Conductance (C) ml O_2 / g / hr °C	0.1101
	C_1 percentage of the predicted value	92.0
(iii)	Mean body temperature °C	36.2

B. *Evaporative water loss* (Ghosh & Purohit, 1969)

Air temperature	Evaporation	
	gm /hr	gm / hr / 100 gm body weight
40 °C	0.62	1.46
42 °C	0.68	1.82
44 °C	1.99	3.04

Table 39. Relationship between food intake and faecal water loss in *M. hurrianae* and other rodent species

Species	Faeces g dry matter/ 100 g food	Water g / 100g dry faecal matter	Water g lost with faeces/ 100g food	Source
Meriones hurrianae	7.8	22.7	1.7	Gaur & Ghosh 1971
Dipodomys merriami	3.0	83.4	2.5	Schmidt-Nielson 1964
Rattus norvegicus	6.0	22.5	13.6	—do—

neral scarcity of drinking water and nutritionally adequate diet. Under such circumstances, its survival mainly depends upon (i) its ability to tolerate high ambient temperature and intense solar radiation encountered during the day with minimum expenditure of water, (ii) its ability to reduce expenditure of water in faeces and urine, and by (iii) maintaining constancy of body fluids by regulating volume and osmotic pressure. In other words, it has developed such physiological adaptations that allow the animals to survive within the thermal as well as water balance after utilizing maximum benefits from available resources in nature. The physiological adaptations of Indian desert rodents have been discussed by Ghosh (1975).

Thermoregulation

Within thermoneutral zone, *M. hurrianae* has low basal metabolic rate (BMR) (0.7897 ml O_2/g/h) and high conductance (0.149 ml O_2/g/hr/°C) which are respectively 67% and 127% of the predicted values based on the body weight criterion (Goyal *et al.*, 1979). A low BMR, high conductance and a comparatively high body temperature (38.7°C) apparently prevent over-heating in these animals. The generally high body temperature of gerbil helps the organism in two ways: (a) heat is stored in its body during surface foraging in day light hours and is periodically unloaded without water expenditure in the cooler environment of the burrow where the animal retreats every now and then and (b) the increased heat gain decreases the gradient between the hot environment and the body, thereby reduces chances of lethal heat gain (Goyal *et al.*, 1979).

The gerbil's tendency to salivate at high ambient temperatures is presumably aimed at delaying lethal hyperthermia, as has been suggested by Hainsworth and Stricker (1970). Such response is part of the rodents physiological defence mechanism against "explosive heat death". A similar reaction has been reported in the Root rat, *Tachyoryctes splendens* (McNab, 1966).

A fall in body temperature from the normal body temperature was observed at 21°C (i.e. below the animals thermoneutral zone) (Table 38), which indicates its poor thermo-regulatory ability at low temperature. This may be due to its high conductance allowing loss of heat instead of conserving the same for the maintenance of body temperature. It has been observed that this gerbil comes out of its burrow for surface foraging early in the morning and late in the afternoon during summer and throughout the day during winter. Apparently, such shifting patterns of diel activity helps the gerbil to withstand extremes of environmental temperatures.

Conservation of Water

Water Requirement: In nature gerbil meets its daily water requirement chiefly from the preformed water in its food and also from the metabolic water produced in its body because free water is not usually available for drinking. However, in the laboratory, daily water consumption was found to be 0.57 per cent of body weight (Ghosh and Gaur, 1966). The summer preference in its diet for locusts containing high percentage of water (Prakash, 1962) may, therefore, be a part of the gerbil's adaptive mechanism to meet its water requirement.

Evaporative water loss: Increase in evaporative water loss with respect to increase in ambient temperature (Ghosh and Purohit, 1964, Table 38) helps the animal to have a comparatively high lethal body temperature which was observed at 43-44°C (Ghosh and Purohit, 1964).

Faecal water loss: Saving of water through faeces is another important adaptive strategy for desert rodents independent of any free water intake. The desert gerbil produces comparatively drier faecal pellets (Gaur and Ghosh, 1971) having only 28% water which is less than that of other desert rodents, *Jaculus orientalis* (Kirmiz, 1962) and *Dipodomys merriami* (Schmidt Nielsen, 1964). Gerbil produces nearly two times more dry faecal pellets per 100 g of food than *D. merriami* (Table 39) which shows its superiority to conserve water through this route.

Urinary water loss: The desert gerbil kidney is efficient in conserving water and excreting urine of high concentrated urinary metabolites (Table 40) thereby conserving the body water under xeric conditions (Ghosh, 1975). In fact, renal mechanism of the *M. hurrianae* (Table 41) is more efficient than that of other animals, as reported by Adolph (1943) and Schmidt-Nielsen *et al.* (1940).

Study by Purohit (1975) on *M. hurrianae* has revealed (i) a high relative medullary thickness of the kidney representing a larger population of long loops of Henle and collecting ducts, (ii) the long loops of Henle and collecting ducts (Table 41) facilitating an increase in osmotic gradient in the renal interstitium extending from the cortical tissue to the tip of renal papillae, and (iii) the collecting ducts becoming more permeable to water molecules, thereby accelerating osmosis against the osmotic gradient set in by the loops of Henle in the renal interstitium. These features collectively lead to production of highly concentrated urine and retention of physiologically useable water, and later recycling into the body fluids through renal blood supply network.

Effects of Water Deprivation

Tolerance during water deprivation: In the laboratory when deprived of water, the desert gerbils survived upto 16 months solely on dry grains (Ghosh and Purohit, 1964). This ability speaks highly of their

Table 40. 24-hours urinary excretion levels in mg of metabolites in gerbils (Ghosh & Purohit, 1964)

Treatment	Chloride	Total electrolytes	Urea	Total nitrogen
Freshly captured	11.03	57	93	82
Dry fed for 60 days	24.30	120	168	153
P value	0.001	0.001	0.001	0.001

Table 41. A comparison of size of glomeruli and their density per 10 × 10 magnification field in gerbils of Rajasthan desert (Jain, 1978)

Species	No. of glomeruli mean ± S. E.	Size of glomerulus (μ) mean ± S. E.
Tatera indica	10.26 ± 0.41	99.48 ± 1.85
Meriones hurrianae	4.00 ± 0.61	148.00
Gerbillus gleadowi	13.71 ± 0.39	67.71 ± 2.57
G. nanus	8.33 ± 0.39	56.68 ± 1.43

physiological mechanism for the conservation of body water.

Body and organ weights: The total body water content of the freshly captured animal was significantly higher ($P<0.01$) than that of the dehydrated desert gerbils (Table 42). Ghosh and Gaur (1966) reported that water deprivation does not affect the weight of kidney, liver, heart, spleen, lungs, pancreas, reproductive tract and alimentary tract in *M. hurrianae*. Apparently the imposed stress although causing significant negative water balance in the animal, failed to cause any desiccation of these organs. This may be due to the utilization of plasma water rather than the intra cellular water contained in the vital organs.

Table 42. Weight of different body organs in g in normally hydrated and water deprived *M. hurrianae* (Ghosh & Gaur, 1966)

Organ	Normally hydrated	Water deprived for 60 days
Adrenals	0.0197	0.0513
Brain	0.8787	0.957
Kidneys	0.3398	0.3618
Liver	1.8528	1.5263
Heart	0.1141	0.1096
Spleen	0.0902	0.0935
Lungs	0.3377	0.3406
Pancreas	0.2301	0.2879
Reproductive tract	0.3230	0.1537
Alimentary tract	1.6487	1.2157

Body fat content: A significant ($P<0.005$) increase in the total body fat content in the dehydrated group of gerbils (Table 43) was indicated (Ghosh and Purohit, 1964). However, no significant variation was observed in the whole body content of either cholesterol or phospholipid between the two groups of animals. Strohl (1929) has also reported localised or general fat accumulations in most of the desert mammals at the beginning of the dry period. These fat deposits are believed to act as efficient water stores since 106 parts of water can be obtained from 100 parts of fat by oxidation. In the present case, the increase in the dehydrated gerbils does not correspond with the cholesterol or phospholipid content implying that only neutral fat components are increased in the dehydrated animals. It would be interesting to find out if these fatty substances are in a liable state or are primarily fat deposits meant as water and energy stores for the body to utilise in times of acute necessity.

Haemoconcentration: The results of blood analysis on freshly captured animals and on animals kept on a dry diet for two months indicated a pronounced and highly significant haemoconcentration in the dehydrated animals (Ghosh *et al.* 1962). The reduction in the average corpuscular haemoglobin content in these animals is related to the significant increase in the number of erythrocytes (Table 43). This increase might be concerned with a higher utilization of the alveolar oxygen.

Urinary metabolites: The urine analysis indicated higher levels of urea, total nitrogen, chloride and total electrolytes in the dehydrated animals than in the freshly captured animals (Table 40). A high salt and a high salt high protein diet when given to the gerbils at different stages of dehydration, produced considerable increase in chloride and total electrolytes in the first case and in chloride, total electrolytes and urea in the second case. These observations indicate that the gerbil kidney is highly efficient in filtering out a large excess of salt and nitrogenous metabolites even when subjected to severe water stress (Ghosh *et al.*, 1964).

Table 43. Effect of water deprivation on body composition and blood constituents in *M. hurrianae* (Ghosh *et al.*, 1962)

Condition of animal	Whole body: Water %	Fat %	Cholesterol %	Phospholipid	Blood constituent: RBC (million/cu. mm)	WBC (thousands/cu.mm	Haemoglobin (g/100 ml)
Freshly captured	70.17	4.04	0.158	0.359	2.35	4.91	12.66
Dry fed for 60 days	59.99	11.62	0.190	0.343	7.29	6.62	16.83

Salt tolerance: The effect of a high salt diet on this gerbil at different stages of dehydration have been extensively studied by Ghosh *et al.* (1962). The maximum salt intake of this gerbil was 0.021 per cent of body weight per day while drinking 0.8 m NaCl solution but it can tolerate salt intake of upto 0.22 per cent of body weight per day for short period (Table 44).

Similarly a significant increase in plasma chloride content (143.5 m Eq/1) from normal (107.8 m Eq/1) was observed when gerbil was provided 1.2 M Nacl solution.

Table 44. Effect of various concentrations of NaCl in drinking solution of fluid intake and salt ingestion in *M. hurrianae* (Ghosh & Gaur, 1966)

	Conc. of NaCl in drinking soln., M						
	0.0	0.2	0.4	0.6	0.8	1.0	1.2
NaCl soln., mg / ml	0.00	11.70	23.40	35.10	46.80	58 60	70.20
Fluid intake	0.57	0.63	0.59	0.51	0.49	0.29	0.18
NaCl ingestion	0.00	0.007	0.013	0.017	0.021	0.016	0.012

BIBLIOGRAPHY

Adams, A. 1899. *Western Rajputana States*. Taylor & Francis, London.

Adolph, E. F. 1943. Do rats thrive when drinking sea water? *Amer. J. Physiol. 140*: 25-32.

Advani, R. and I. Prakash. 1979a. New object reaction in *M. hurrianae* (Ms).

Advani, R. and I. Prakash. 1979b. Behaviour of *M. hurrianae* after recovery from deprivation. *Behavioural Processes* (in press).

Agrawal, V. C. 1962. Taxonomic study of skull of oriental rodents in relation to ecology. *Rec. Indian Mus. 60* : 125-326.

Agrawal, V. C. 1965. Field observations on the biology and ecology of the desert gerbil, *Meriones hurrianae* (Rodentia, Muridae) in western India. *J. Zool. Soc. India 17* : 125-135.

Ahmed, E. 1969. Origin and geomorphology of the Thar Desert. *Ann. Arid Zone 8* : 171-180.

Anonymous, 1908. *The Imperial Gazetter of India*. Clarendon Press, Oxford.

Ashby, K. R. 1967. Studies on the ecology of field mice and voles (*Apodemus sylvaticus, Clethrionomys glareolus* and *Microtus agrestis*) in Hougha'l Wood, Durham, *J. Zool. 152* : 3 & 9-513.

Barnett, S. A. 1966. The feeding of rodents. *Indian Rodent Symp.* Calcutta, 113-123.

Barnett, S. A. and I. Prakash. 1975 *Rodents of Economic Importance in India.* Arnold Heinemann, New Delhi & Heinemann, London, 1-175.

Blanford, W. T. 1988-91. *The Fauna of British India including Ceylon and Burma. Mammalia* (Vols 1 & 2). Taylor and Francis, London.

Bodenheimer, F. S. 1957. The ecology of mammals in arid zones. in *Human and Animal Ecology*, Reviews of Arid Zone Research, 8 : 100-137, UNESCO, Paris.

Brody, S. 1945. The time relations of growth of individuals and populations. Chapter XVI in *Bioenergetics and Growth* : 487-574. Reinhold, New York.

Burt, W. H. 1940. Territorial behaviour and populations of small mammals in southern Michigan. *Miscl. Publ. Mus. Zool., Univ. Michigan 45* : 1-58.

Burt, W. H. 1943. Territoriality and home range concepts as applied to mammals. *J. Mamm. 26*: 346-352.

Butterworth, B. B. 1961. A comparative study of growth and development of the Kangaroo rats, *Dipodomys deserti* Stephens and *Dipodomys merriami*. *Growth 25*: 127-138.

Cainfield, R. H. 1941. Application of the line intercept method in sampling vegetation. *J. For. 39*: 388-394.

Chaworth-Musters, J. C. and J. R. Ellerman. 1947. A revision of the genus *Meriones*. *Proc. Zool. Soc.* London *177* : 478-504.

Comber, E. 1910. Food of desert gerbil (*Gerbillus hurrianae*). *J. Bombay nat. Hist. Soc. 19* : 978.

Cott, H. B. 1951. The palatability of the eggs of birds: Illustrated by experiments on the food preference of the hedgehog (*Erinaceus europaeus*), *Proc. Zool. Soc. London 121* : 1-41.

Daly, M. 1977. Some experimental tests of the functional significance of scent-marking by gerbil (*Meriones unguiculatus*) *J. Comp. Physiol. & Psychol. 91* : 1082-1094.

Dominic C. J. 1974. Role of pheromones in mammalian fertility. Proc. Int. Symp. on *Neuro-endocrine regulation of fertility*, Kanpur, 236-245.

Eisenberg, J. F. 1963. The behaviour of heteromyid rodents. *Univ. Calif. Publ. Zool. 69* : 1-100.

Eisenberg, J. F. 1967. A comparative study in rodent ethology with emphasis on evolution of social behaviour, I. *Proc. U. S. Natl. Mus. 122* (359) : 1-51.

Eisenberg, J. F. 1975. The behaviour patterns of desert rodents. Chapter X in *Rodents in Desert Environments* (Eds. I. Prakash and P. K. Ghosh) Dr. W. Junk b. v. Publishers, The Hague : 189-224.

Ellerman, J. R. 1940-41-47. *The Families and Genera of living rodents.* British Mus. (Nat. Hist.) Vols 1 to 3.

Ellerman, J. R. 1961. *The Fauna of India including Pakistan, Burma and Ceylon, Mammalia.* 3 (1&2) Manager of Publ. Govt. of India, New Delhi.

Fitch, H. S. 1957. Aspects of reproduction and development in the Prairie vole (*Microtus ochrogaster*) *Univ. Kansas Publ. Miscl. Nat. Hist. 10* : 129-161.

Fitzwater, W. D. and I. Prakash. 1966, 1973, 1978. *Handbook of Vertebrate Pest Control*, ICAR. New Delhi. (Mimeo, I and II Edition) : 1-95.

Fitzwater, W. D. and I. Prakash. 1969. Burrows, behaviour and home range of the Indian desert gerbil, *Meriones hurrianae* (Jerdon). *Mammalia 33* : 598-606.

Ganguli, B. N. and R. N. Kaul, 1962. Preliminary study on the behaviour and control of the Indian desert gerbil (*Meriones hurrianae*). *Indian For. 88* : 297-304.

Gaur, B. S. and P. K. Ghosh. 1971. Effect of water deprivation in faecal water loss in the Indian desert gerbil, *Meriones hurrianae* (Jerdon) *J. Anim. Morphol. Physiol. 18* : 121-126.

Ghosh, P. K. 1968. *Annual Report CAZRI*, Jodhpur (Mimeo).

Ghosh, P. K. 1975. Thermo-regulation and water economy in Indian desert rodents. Chapter XX in *Rodents in Desert Environments* (Eds. I Prakash and P. K. Ghosh) Dr. W

Junk b. v. Publishers, The Hague : 397-412.

Ghosh, P. K. and B. S. Gaur. 1966. A comparative study of salt tolerance and water requirements in desert rodents, *Meriones hurrianae* and *Gerbillus gleadowi. Indian J. Exptl. Biol. 4* : 228-230.

Ghosh, P. K., S. P. Goyal and I. Prakash. 1979. Metabolism and ecophysiology of Rajasthan desert rodents. Thermo-regulation at a moderately low temperature (21°C) during winter. *J. Arid Environments 2* : 77-83.

Ghosh, P. K. and K. G. Purohit. 1964. Effects of water stress on gross body composition and renal function in small desert mammals. *Proc. UNESCO/India Symp. Problems of Indian Arid Zone,* Jodhpur : 298-304.

Ghosh, P. K., K. G. Purohit, and I. Prakash. 1962. Studies on the effects of prolonged water deprivation on the Indian desert gerbil, *Meriones hurrianae. In Environ. Physiol. Psychol.* Proc. Lucknow Symp. UNESCO Paris : 301-306.

Ghosh, P. K. and G. C. Taneja. 1968. Oestrous cycle in the desert rodents, *Tatera indica* and *Meriones hurrianae. Ind. J. Exptl. Biol. 6* : 54-55.

Glenn, M. and J. Gray. 1965. Effect of various hormones on the growth and histology of gerbil, (*Meriones unguiculatus*) abdominal sebaceous gland pad. *Endocrinology 76* : 1115-23.

Goyal, S. P., P. K. Ghosh and I. Prakash. 1979. Some physiological adaptive mechanisms of the Indian desert gerbil, *Rodent Newsletter,* 3(3) : 17-18.

Gupta, R. K. and I. Prakash. 1975. *Environmental Analysis of the Thar Desert.* Eng'ish Book Depot, Dehra Dun : 1-484.

Hainsworth, F. R. and E. M. Stricker. 1970. Salivary cooling by rats in the heat. In *Physiological and Behavioural Temperature Regulation* (Eds. J. D. Hardy, A. P. Gagge and J. A. J. Stolwijk): 611-626. Charles C. Thomas Publ. Sringfield, Illinois.

Hughes, R. L. and I. Rowley. 1965. Breeding season of female wild rabbits in natural population in the Riverina and southern Tableland districts of New South Wales. *CSIRO Wildl. Res. 11* : 1-10.

Hynes, H. B. N. 1950. The food of fresh water stickelbacks (*Gastrosteus aculeatus* and *Pygosteus pangitius*) with a review of the food of fishes. *J. Anim. Ecol. 19* : 36-58.

Jackson, W. B. 1952. Population of wood mouse (*Peromyscus leucopus*) subjected to the application of DDT and parathion. *Ecol. Monogr. 22* : 259-281.

Jain, A. P. 1970. Body weights, sex ratio, age structure and some aspects of reproduction in the Indian gerbil, *Tatera indica indica* Hardwicke in the Rajasthan desert. *Mammalia 34* : 415-432.

Jain, A. P., I. Prakash and B. D. Rana. 1975. Baits for the control of the Cutch Rock rat, *Rattus cutchicus cutchicus* Wroughton. *Proc. All India Rodent Seminar,* Ahmedabad:

Jain, A. P., I. Prakash and B. D. Rana. 1975. Morphological variation in the rats inhabiting the Indian desert. *Acta Theriol. 20* : 133-140.

Jerdon, T. C. 1867. *Mammals of India.* Thacker and Spink, Simla, 1-319.

Kaul, D. K. and L. S. Ramaswami. 1969. Reproduction in the Indian desert gerbil, *Meriones hurrianae* (Jerdon) *Acta Zoologica 50* : 233-248.

Kashkarov, D. and V. Kurbotov. 1930. Preliminary ecological survey of two vertebrates of central Karakum Desert in Western Turkestan. *Ecology. 11* : 35-60.

Kirmiz, J. P. 1962. *Adaptation of Desert Environment* : A study on the Jerboa, rat and man. Butterworth, London.

Krishnan, M. S. 1952. Geological history of Rajasthan and its relation to present day conditions. Symp. Rajputana Desert. *Bull. Natl. Instt. Sci,* India, *1* : 19-31.

Kumari, Saroj, P. E. Cowan and I. Prakash. 1979. Observations on the mid-ventral marking gland of the Indian desert gerbil, *Meriones hurrianae. Z. Saught.* (In press).

Mann, G. S. 1975. Crop preference of rodents in Ludhiana. *J. Bombay nat. Hist. Soc. 72* : 383-392.

Mathur, R. P. and I. Prakash. 1979. New food reaction among desert rodents. *Saug. Mitteil.* (In press).

McCann, C. 1927. Note on the desert gerbil (*Cheliones hurrianae*). *J. Bombay nat. Hist. Soc. 32* : 213.

McNab, B. K. 1966. The metabolism of fossorial rodents : a study of convergence. *Ecology 47*: 712-733.

Minton, S. A. 1966. A contribution to the herpetology of west Pakistan. *Bull. Amer. Mus. nat. Hist. 134*(2) : 27-184.

Muthana, K. D. 1975. Maternal behaviour of a desert gerbil. *J. Bombay nat. Hist. Soc. 72* : 837-838.

Parker, R. N. 1924. *A Forest Flora of the Punjab, with Hazara and Delhi.* Govt. Printing Press, Punjab, Lahore.

Petter, F. 1961. Repartition geographique et ecologie des rongeurs desertiques (du Sahara occidental a l'Iran Oriental). *Mammalia,* 25 (No. Special): 1-222.

Phillips, W. W. A. 1923. Some notes on the habits of Ceylon gerbil, *Tatera ceylonica. J. Bombay nat. Hist. Soc.* 29: 214-216.

Pocock, R. I. 1939-41. *The Fauna of British India including Ceylon and Burma, Mammalia.* Vol. I & II, Taylor and Francis, London.

Prakash, I. 1957. A survey and ecological studies of the mammals of the desert of Rajasthan. Ph. D. thesis, University of Rajasthan, Jaipur.

Prakash, I. 1958. Extinct and vanishing mammals from the desert of Rajasthan and the problem of their preservation. *Indian For. 84* : 642-645.

Prakash, I. 1959a. Hypertrophy of Bullae tympanicae in the desert mammals. *Sci. & Cult. 24* : 580-582.

Prakash, I. 1959b. Foods of Indian desert mammals. *J. Biol. Sci. 2* : 100-109.

Prakash, I. 1959c. Food of certain insectivores and rodents in captivity. *Univ. Raj. Studies* (B), *IV* : 1-18.

Prakash, I. 1959d. Destruction of vegetation by desert animals in Rajasthan. *Indian For. 85* : 251-253.

Prakash, I. 1960. Breeding of mammals in Rajasthan desert, India. *J. Mamm. 42* : 386-389.

Prakash, I. 1962. Ecology of gerbils of the Rajasthan desert India. *Mammalia 26* : 311-331.

Prakash, I. 1962. Taxonomical and ecological account of the mamma's of Rajasthan Desert. *Ann. Arid Zone* *1* : 143-162, *2*(2) : 150-161.

Prakash, I. 1963a. Zoogeography and evolution of the mammalian fauna of Rajasthan desert. *Mammalia* *27* : 342-351.

Prakash, I. 1963b. Destructive rodent of desert grassland. *Gosamvardhana* *XI* : 15-18.

Prakash, I. 1964a. Ecology of the Indian desert gerbil, *Meriones hurrianae* Jerdon. Proc. *UNESCO/India Symp. Problems of Indian Arid Zone,* Jodhpur : 305-310.

Prakash, Ishwar. 1964b. Ecotoxicology and control of the Indian desert gerbil, *Meriones hurrianae* Jerdon. Pt. II. Breeding season, litter size and post-natal development. *J. Bombay nat. Hist. Soc. 61* : 142-149.

Prakash, I. 1964c. Cytomorphology of the adrenal gland of the Indian desert gerbil. *J. Anat. Soc. India 8* : 76-79.

Prakash, I. 1968 (1978) Biology of the rodents of Rajasthan desert. *Proc. Symp. Natural Resources of Rajasthan,* Univ. Jodhpur : 337-352.

Prakash, I. 1969. Eco-toxicology and control of Indian desert gerbil, *Meriones hurrianae* Jerdon. V. Food preference in the field during monsoon. *J. Bombay nat. Hist. Soc.* *63*(3): 581-589.

Prakash, I. 1971a. Eco-toxico'ogy and control of the Indian desert gerbil, *Meriones hurrianae* (Jerdon) Pt. VIII. Body weight, sex ratio and age structure. *J. Bombay nat. Hist. Soc. 68*(3): 717-725.

Prakash, I. 1971b. Breeding season and litter size of Indian desert rodents. *Zeit. f. angewandte Zool. 58*(4): 442-454.

Prakash, I. 1972 Eco-toxicology and control of the Indian desert gerbil, *Meriones hurrianae* (Jerdon) IX. Ecological distribution in the Rajasthan desert. *J. Bombay nat. Hist. Soc. 69*: 510-517.

Prakash, I. 1973. Rodent damages in the field and their control in prevention of waste and loss of foodgrains. *National Productivity Council III* : 287-295.

Prakash, I. 1974. The ecology of vertebrates of the Indian desert. Chapter XIII in *Biogeography and Ecology in India.* (Ed. M. S. Mani) Dr. Junk b. v. Publishers, The Hague : 369-420.

Prakash, I. 1975a. Population ecology of rodents in the Rajasthan desert, India. Chapter V in *Rodents in Desert Environments* (Eds. I. Prakash and P. K. Ghosh) Dr. W. Junk b. v. Publishers, The Hauge : 75-186.

Prakash, I. 1975b. The ecology and zoogeography of mammals. Chapter XIX in *Environmental Analysis of the Thar Desert* (Eds. R. K. Gupta and I. Prakash) English Book Depot, Dehra Dun : 448-467.

Prakash, I. 1975c. Wi'dlife ecology and conservation. Chapter XX in *Environmental Analysis of the Thar Desert* (Eds. R. K. Gupta and I. Prakash) English Book Depot. Dehra Dun : 468-480.

Prakash, I. 1975d. The Amazing Life in the Indian desert. *Illustrated Weekly Annual,* 96-121 (Reprinted as CAZRI Monograph No. 6 (1977), 1-16.

Prakash, I. 1976. Rodent Pest Management—Principles and Practices, CAZRI Monograph No. 4, 1-28.

Prakash, I. 1978. Impact of changing land use pattern on the rodent communities in part of the Indus basin. *Proc. Natl. Symp. Land and Water Management in the Indus Basin* (India): 481-486.

Prakash, I., W. D. Fitzwater and A. P. Jain. 1970. Toxic chemicals and baits for the control of the gerbils. *Meriones hurrianae* Jerdon and *Tatera indica* Hardwicke. *J. Bombay nat. Hist. Soc. 66* : 500-509.

Prakash, I. and P. K. Ghosh. 1975. *Rodents in Desert Environments.* Dr. W. Junk b. v. Publishers, The Hague. 1-624.

Prakash, I., R. K. Gupta, A. P. Jain, B. D. Rana and B. K. Dutta. 1971. Ecological evaluation of rodent populations in the desert biome of Rajasthan. *Mammalia 35* : 384-423.

Prakash, I and A. P. Jain. 1971. Bait shyness of two gerbils, *Tatera indica* and *Meriones hurrianae. Ann. Applied Biol.* 69(2) : 169-172.

Prakash, I., A. P. Jain and B. D. Rana. 1975a. A study of field populations of rodents in the Indian desert, IV. Ruderal habitat. *Zeit. f. angew. Zool. 62* : 339-348.

Prakash, I., A. P. Jâin and B. D. Rana. 1975b. Baits for the control of Hairy footed gerbil, *Gerbillus gleadowi* Murray. *Z. f. angew. Zool. 62*: 349-359.

Prakash, I. and Saroj Kumari. 1978. Morphological variation in *Meriones hurrianae* (Jerdon, 1867) inhabiting two bioclimatic zones in the Indian desert. *Saug. Mitteil. 26* : 281-284.

Prakash, I. and Saroj Kumari. 1979. Occurrence of ventral marking gland in desert rodents. *Saug. Mitteil. 27* : 315-316

Prakash, I. and C. G. Kumbkarni. 1962. Ecotoxicology and control of Indian desert gerbil, *Meriones hurrianae* (Jerdon) I. Feeding behaviour, energy requirements and selection of bait. *J. Bombay nat. Hist. Soc. 59* (3): 800-806.

Prakash, I., C. G. Kumbkarni and A. Krishnan. 1965. Eco-toxicology and control of the Indian desert gerbil, *Meriones hurrianae* III. Burrow temperature. *J. Bombay nat. Hist. Soc. 62* : 237-244.

Prakash, I. and K. G. Purohit. 1966. Some observations on the hairy footed gerbil, *Gerbillus gleadowi* Murray, in the Rajasthan desert. *J. Bombay nat. Hist. Soc. 63* : 431-434.

Prakash, I., K. G. Purohit and L. R. Kametkar. 1967. Intake of seeds of grass, shrub and tree species by three species of gerbils in Rajasthan desert. *Indian For. 93* : 801-805.

Prakash, I. and B. D. Rana. 1970. A study of field population of rodents in the Indian desert. *Zeit. f. angew. Zool. 57* : 129-136.

Prakash, I. and B. D. Rana. 1972. A study of field population of rodents in the Indian desert. II. Rocky and piedmont zones. *Zeit. f. angew. Zool. 59* : 129-139.

Prakash, I. and B. D. Rana. 1973. A study of field population of rodents in the Indian desert. III. Sand dunes in 100 mm rainfall zone. *Zeit. f. angew. Zool. 60* : 31-41.

Prakash, I., B. K. Soni and R. P. Mathur. 1978. Baits for the control of Indian desert gerbil, *Meriones hurrianae* Jerdon. *Z. angew. Zool. 65* : 303-312.

Prakash, I. and G. C. Taneja. 1969. Reproduction biology of the Indian desert hare, *Lepus nigricollis dayanus* Blanford. *Mammalia 33* : 102-117.

Prakash, I., G. C. Taneja and K. G. Purohit. 1971. Eco-toxicology and control of Indian desert gerbil, *Meriones hurrianae* Jerdon. VII. Relative numbers in relation to ecological factors. *J. Bombay nat. Hist. Soc. 68*(1): 86-93.

Pramanik, S. K. and P. S. Hariharan. 1952. The climate of Rajasthan. Symp. Rajputana Desert. *Bull. Natl. Instt. Sci. 1* : 167-178.

Prasad, M. R. N. 1954. Food of Indian gerbil, *Tatera indica cuvieri* Waterhouse. *J. Bombay nat. Hist Soc. 52* : 321-325.

Prater, S. H. 1948. *The Book of Indian Animals*. Bombay Natural History Society, Bombay (Revised Edn. 1965): 1-323.

Purohit, K. G. 1975. Histomorphology of kidney in the Indian desert gerbil, *Meriones hurrianae* and its ecophysiological appraisal. *Zeitsch. f. angew. Zool. 62* : 9-21.

Purohit, K. G., L. R. Kametkar and I. Prakash. 1966. Reproduction biology and post-natal development in the Northern palm squirrel, *Funambulus pennanti* Wroughton. *Mammalia 30* : 538-546.

Rana, B. D., A. P. Jain and I. Prakash. 1975. Morphological variation in in the gerbils inhabiting the Indian desert. *Acta. Theriol. 20* : 123-132.

Rana, B. D., I. Prakash and A. P. Jain. 1970. Morphological variation in *Tatera indica* Hardwicke, 1807, inhabiting two types of Indian desert habitats. *Acta Theriol. 15* : 459-464.

Reichman, O. J., I. Prakash and V. Roig. 1979. Food selection and consumption. Chapter 29 in IBP Arid Land Synthesis. Cambridge University Press, London *16* : 685-716.

Roberts, T. J. 1977. *The Mammals of Pakistan*. Ernest Benn Ltd., London : 1-361.

Roonwal, M. L. 1949. Systematics, ecology and bionomics of mammals studied in connection with tsutsugamustri disease (scrub typhus) in the Assam-Burma war theatre during 1945. *Trans. Natl. Instt. Sci.*, India *3*(2) : 67-122.

Roonwal, M. L. 1950. Contributions to the fauna of Manipur State, Assam, Pt. III. Mammals, with special reference to the family muridae (Order Rodentia). *Rec. Indian Mus. 47* : 1-64.

Roy, B. B. and A. K. Sen. 1968. Soil map of Rajasthan. *Ann. Arid Zone 7* : 1-14.

Ryley, K. V. 1913. Bombay Natural History Society's Mammal Survey of India. Report No. 10. *J. Bombay nat. Hist. Soc. 22* : 414-513.

Rzoska, J. 1954. The behaviour of white rats towards poison baits. In *Control of rats and mice* (eds. Dennis Chitty and H. S. Southern). Oxford : Clarendon Press.

Schmidt-Nielsen, K. 1964. *Desert Animals*. Oxford University Press London.

Schmidt-Nielsen, K., B. Schmidt-Nielsen and H. Schneiderman. 1948. Salt excretion in desert mammals. *Amer. J. Physiol.* 154 : 163-166.

Sharma, V. N. and M. C. Joshi. 1975. Soil excavated by desert gerbil *Meriones hurrianae* (Jerdon) in the Shekhawati region of Rajasthan desert. *Ann. Arid Zone 14*: 268-273.

Smith, R. E. 1958. Natural history of the prairie dog in Kansas. *Univ. Kansas Mus. Nat. Miscel. Pub. 16* : 1-36.

Spillet, J. J. 1968. The ecology of the lesser bandicoot rat in Calcutta. Bombay Natural History Society and Johns Hopkins. CMRT : 1-223.

Strohl, J. 1929. Wasserhaushalt and Fettbesttand bei steppen-und Wustentiesen. *Verh. naturf. Ges. Basel 40* : 422-440.

Taber, R. D., A. N. Sheri and M. S. Ahmed. 1967. Mammals of the Lyallpur region, West Pakistan. *J. Mamm. 48* : 392-407.

Thiessen, D. D., K. Owen and G. Lindzey. 1971. Mechanisms of territorial marking in the male and female Mongolian gerbil (*Meriones unguiculatus*) *J. Comp. & Physiol. Psychol.*, 77 : 38-47.

Thiessen, D. D. and P. Yahr. 1977. *The Gerbil in Behavioural Investigations. Mechanisms of Territoriality and Olfactory Communication.* Univ. Texas Press, Austin and London : 1-224.

Thiessen, D. D., P. Yahr and K. Owen. 1973. Regulatory mechanisms of territorial marking in the Mongolian gerbil. *J. Comp. & Physiol. Psychol. 82* : 382-393.

Thomas, O. 1919. Notes on the gerbils referred to the genus *Meriones*, with descriptions of new species and subspecies. *Ann. Mag. Nat. Hist.* ser. 9), 3 : 263-273. (A number of publications on Indian mammals have appeared in this Journal and *J. Bombay nat. Hist. Soc.* during 1897-1925.

Wadia, D. N. 1960. The post-glacial desiccation of Central Asia. Monogr. 10, *Natl. Instt. Sci. India* : 1-25.

Wagle, P. V. 1927a. Injurious field rats of lower Sind and their extermination. Dept. Agri. Bombay.

Wagle, P. V. 1927b. The rice rats of lower Sind. *J. Bombay nat. Hist. Soc. 32* : 330-338.

Webster, D. B. 1960. Auditory significance of the hypertrophied mastoid bullae in *Dipodomys*. *Anat. Rec. 136* : 299.

Wroughton, R. C. 1905-23. Summary of the results from the Indian Mammal Survey of the Bombay Natural History Society and scientific results from the Mammal Survey. A number of these reports appear in *J. Bombay nat. Hist. Soc.*

The desert gerbil is the most successful denizen of the Indian arid environment.

CAZRI MONOGRAPH SERIES

No. 1	Desert Ecosystem and its Improvement, pp. 1-387 (1974).	Edited by H. S. Mann
No. 2	Proceedings of Summer Institute on Rodentology (Mimeo.), pp. 1-365 (1975).	Edited by Ishwar Prakash
No. 3	Solar Energy Utilization Research (Mimeo.), pp. 1-48 (1975).	by H. P. Garg
No. 4	Rodent Pest Management — Principles and Practices, pp. 1-28 (1976).	by Ishwar Prakash
No. 5	White Grubs and their Management, pp. 1-30 (1977).	by S. K. Pal
No. 6	The Amazing Life in the Indian Desert, pp. 1-18 (1977).	by Ishwar Prakash
No. 7	Geomorphological Investigations of the Rajasthan desert, pp. 1-44 (1977).	by Surendra Singh
No. 8	Proceedings of Summer Institute on "Resource Inventory and landuse planning", pp. 1-373 (1977).	Edited by K. A. Shankarnarayan
No. 9	Land Use Classification System in Indian Arid Zone, pp. 1-43 (1978).	by Amal Kumar Sen