MISCELLANEOUS PUBLICATION
OCCASIONAL PAPER NO. 105

Records of the Zoological Survey of India

Recent advances in Rodentology in India

M.L. Roonwal

Issued by the Director
Zoological Survey of India, Calcutta

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RECENT ADVANCES IN RODENTOLOGY IN INDIA

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सत्यमेव जयते

Edited by the Director, Zoological Survey of India.
1987

Published : December 1987

PRICE : Inland : Rs. 70.00
Foreign : £ 10.00, $ 13.00

PRINTED AT DOON PHOTOTYPE PRINTERS, 14, OLD CONNAUGHT PLACE
DEHRADUN—248001
AND PUBLISHED BY THE DIRECTOR ZOOLOGICAL SURVEY OF INDIA,
CALCUTTA—700053

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MISCELLANEOUS PUBLICATION
Occasional Paper

No. 105 | 1987 | Page : 1—126

CONTENTS

I-INTRODUCTION

Rodents, especially rats and their allies, have always been with us, mostly as pests, ever since primitive man became an agriculturist and started having graneries. Before that, as a hunter-gatherer, he was probably not pestered by rodents. The larger rodents such as porcupines and the largest one, the capivara of Brazil (*Hydrochoreus hydrochoeris* L., vide Roonwal, 1962, for a coloured picture), must have been welcome sources of food. The Chinese are said to relish rat meat as a delicacy. In Hindu mythology rats always accompany the popular diety, the elephant-headed Ganesh* (Fig. 1) (the son of Shiva and his consort Parvati), the harbinger of prosperity, success and abundance (*riddhi, siddhi, vriddhi*), whose blessings are invoked at the start of all functions such as weddings and religious ceremonies.

Rodents, especially rats, have attracted the attention of naturalists in India for a long time, but the work carried out was mostly of a general nature. In the early part of the present century, rodent work was intensified largely due to the spread of the flea-borne bubonic plague epidemic, the rat being the reservoir of infection (the primary host). In the same period, taxonomic study received a great fillip due to the operation of the Government of India's Mammal Survey programme.

The first comprehensive account of the rodent of the Indian Region was by Blanford in his volume on *Mammalia* (1888-1891, in the *Fauna of British India* series) and included the order Rodentia proper (the Simplicidentata) and the Lagomorpha (the Duplicidentata, e.g., the Leporidae and Ochotonidae, now separated as a distinct order). The Simplicidentata included 93 species and 14 varieties. (The earlier accounts, viz., those of Jerdon 1867 and Sterndale 1884, are less complete.) The next major taxonomic contributions were the 3-volume work of Ellerman (1940-1949, *The Families and Genera of Living Rodents*) and the account of rodents in the *Checklist* of Ellerman and Morrison-Scott (1951, amendments 1953).* Finally, the third and until today the standard work is the volume on Rodentia (as a second edition of Blanford's *Mammalia* volume) by Ellerman

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***Also known by a variety of other names, eg. Ganapati, Gajanand and Vinayak.**

*For generic names and higher taxa, vide the basic work of Simpson (1945) and the more recent memoir of Honacki et al. (1982).

Figure 1. The Hindu godhead, Ganapati or Ganesh, with his customary associate, the rat. (From a contemporary print.).

(1961, with an Appendix by Roonwal and Biswas). It included 46 genera, 128 species and 260 subspecies; since then, a few genera and species have been added to the Indian fauna, The six families included were:

1. Sciuridae (squirrels).
2. Hystricidae (porcupines).
3. Dipodidae (jerboas and birch-mice).
4. Muscardinidae (dormice).
5. Rhizomyidae (bamboo-rats).
6. Muridae (rats, mice, bandicoots, hamsters, voles, gerbils, etc.).

The area covered in the regional accounts mentioned above was what is known broadly as the Indian Region and included India, Pakistan, Nepal, Bhutan, Bangladesh and Sri Lanka.

The larger amount of work done in recent years has been concentrated mostly on rodents of economic importance and their control; the other species have been dealt with relatively cursorily. All this work has been possible largely through the support received from the Indian Council of Agricultural Research and the Indian Council of Medical Research and some other agencies. As a consequence, a few centres of work have sprung up, principally the following :—

1. Central Arid Zone Research Institute, Jodhpur. (Ecology and control of desert rodents, especially gerbils. Dr. I. Prakash, Dr. P.K. Ghosh and Dr. A.P. Jain.)

2. Department of Zoology, Punjab Agricultural University, Ludhiana. (Ecology and control. Dr. O.S. Bindra, Dr. S.S. Guraya and Dr. V.R. Parshad.).

3. Grain Storage Technology Institute, Hapur, U.P.), (Control of house rats. Dr. K. Krishnamurthy.)

4. Rodent Control Project, Sidhpur, Gujarat). (Control in villages. Dr. G.C. Chaturvedi. The Rodentological Society of India located here brings together the country's rodentologists.)

5. Department of Vertebrate Zoology, Agricultural University, Bangalore. (Ecology and control. Dr. Durairaj and Dr. Srihari.).

6. Central food Research Institute, Mysore. (Ecology and control of urban rodents. Dr. M.K. Krishnakumari.).

7. Mammal Section, Zoological Survey of India, Calcutta. (Taxonomy and field ecology. Dr. V.C. Agarwal, Dr. S. Chakraborty and others.)

8. Virus Research Institute, Pune, Maharashtra. (Status in spread of virus diseases. Dr. V. Dhanda.).

9. The various research centres under the I.C.A.R's National Programme of Rodent Pest Management, since 1975. The Co-ordinator of these schemes (successively Dr. I. Prakash, Dr. P.K. Ghosh and Dr. A.P. Jain) is located at the Central Arid Zone Research Institute, Jodhpur; he also publishes, since 1977, a slim quarterly periodical, *Rodent News letter,* for short, preliminary communications.

In the past, rodent work had been done at the following centres which, however, have now practically ceased to do active rodent work :- The Haffkine Institute, Bombay; the Johns Hopkins University Rodent Centre, Calcutta; and the Department of Zoology and Entomology at the U.P. Agricultural Research Institute, Kanpur.

In recent years several symposia and seminars on rodents have been held at th national and international levels, besides gatherings dealing with vertebrate pests which include rodents. The more important ones which contain material of Indian interest are as follows, the last four dealing exclusively with Indian rodents (for more details, vide infra, the Bibliography).

1. GENEVA. 1966. Seminar on Rodents and Rodent Ectoparasites (Geneva, Oct. 1966).-Geneva (W.H.O.).

2. HONOLULU. 1968. Rodents as Factors in Disease and Economic Loss (Honolulu, June 1968). - Honolulu (Asia-Pacific Interchange).

3. CALCUTTA. 1966 (1969). Indian Rodent Symposium (Calcutta, Dec. 1966) 314 + 1 pp. - Calcutta (U.S.A.I.D.). Published 1969.

4. KANPUR. 1968 (1971). International Symposium on Bionomics and Control of Rodents. (Kanpur, Sept. - Oct. 1968). - Kanpur (Sci. and Technol. Soc.). Published 1971. (Ed. by S.L. Perti, T.C. Wal and C.P. Srivastava.)

5. JODHPUR. 1975. Summer Institute on Rodentology (Jodhpur, June-July 1975). - Jodhpur (Central Arid Zone Res. Inst.).

6. AHMEDABAD. 1975. All-India Rodent Seminar (Ahmedabad, Sept. 1975). - Sidhpur (Rodent Control Project).

The economic importance of rodents :

Commensal rats and mice are, next to man, the most destructive of the vertebrate pests. The most widespread of these are the Norway Rat (*Rattus norvegicus*), the black rat (*Rattus rattus*) and the house mouse (*Mus musculus*). In addition, there are species of local and regional importance. A few figures of lossess, as given by Dykstra (1968), would suffice to show the extent of damage caused by rodents.

In the world about 33 million tons (or 3.6 per cent of total production) of bread grains and rice in storage are annually lost through rodents. Rats eat about 10 per cent of their own weight as food each day, and damage more by their urine and droppings. A rat left free to roam in a warehouse for a year would consume about 12 kilograms of food and deposit about 25,000 droppings weighing 1 to 2 kilograms. The Hawaian sugar industry suffers an annual loss of 4,500,00 U.S. dollars. In 1953 there were an estimated 100 million rats in the U.S.A., each causing 10 dollars worth of damage.

Some figures of losses in India would be of interest. Rodents destroy about 25 per cent of grain in the field, and another 25-30 per cent in storage. In 1952, the loss of food grains in the Punjab was estimated at 0.16 million tons worth over Rs. 5 crores (50 million) (Patnaik 1969). In Uttar Pradesh alone the annual loss to sugarcane due to rats is about Rs. 66.50 per hectare or Rs. 78,800,000/- for the entire State (K.M. Gupta et al. 1971). In most parts of the country all kinds of grains (wheat, bajra, jowar, maize, rice, etc.) and other crops such as sugarcane, groundnut and coconut, are damaged. Rats are known to tunnel the protective bunds of water reservoirs and cause the flooding of extensive areas. There is at least one rail wagon derailment every year in the railway yards due to rats burrowing under the railway track. All kinds of materials are gnawed by rodents; 70 per cent of the wooden doors in crowded localities in Bombay are gnawed by rats (Patnaik 1969).

Rodents are reservoirs of several diseases such as bubonic plague, rabies, tularemia, scrub typhus, tick typhus, infective jaundice, etc. (Beltazar 1966, Howard 1968). In India during the 50-year period ending 1948, about 12,597,749 persons died due to plague (Patnaik 1969).

Aircraft have to be protected against rodents especially to prevent transport of rodents carrying plague or other diseases from one part of the world to another, considering that in a few hours an aeroplane can carry a

rodent from an infected to a free area thousands of miles away (Geary 1968). Runways of airfields are subject to burrowing by rodents.

The object of the present review is to take stock of the vast amount of literature that has been published in the last twenty-five years or so in widely scattered places (over 1,000 references are listed in the Bibliography at the end) for the facility of professional rodentologists, and others who may be interested in rodents. Also to suggest future lines of work on all aspects of rodentology so as to ensure a more balanced undrestanding of this large and economically important mammalian group.

II - GENERAL ASPECTS

(Bibliograhies, Reviews, Symposia, Mythology, etc.)

The largest single bibliography of world rodents (period 1970-1974) is that issued by the Food and Agricultural Organisation of the U.N. (1977) and includes nearly 6,000 references; a brief abstract accompanies each reference, and there is a species index and a geographical index. The arrangement of the references, however, does not seem to follow any system, and the authors are arranged neither alphabetically nor chronologically. More restricted bibliographies will be found in Barnett (1975, the rat) and Barnett and Prakash (1975, Indian rodents).

Several symposia have been held in recent years both at the world and the All-India levels (for details, vide supra, the Introduction, and infra, the Bibliography).

Rats invariably accompany Ganesh, an importang godhead of the Hindu pantheon. Malhotra (1969) has discussed the place of rodents in Hindu rituals and (1975) the social aspects of rodent control. Advani (1980) has discussed how the tribal people in India perceive rodent control operations.

Breeding techniques in the laboratory have been discussed by Urs et al. (1971, ratteries) and A.S. Srivastava, Tripathi and Awasthi (1971).

III - TAXONOMY AND DISTRIBUTION

(Faunistics, Classification, Taxonomy, Distribution, Zoogeography, Fossils)

The basic contributions are those by Ellerman (1940-1961) and Ellerman and Morrison-Scott (1951, 1953). More restricted accounts are those by Roonwal (1948, 1949b, 1950), Roonwal and Biswas (1961), Biswas and Tiwari (1969), Moore (1959, 1960), Moore and Tate (1965),

Marshall (1977), V.C. Agarwal (1967a, b, 1974, 1976) and others (also vide infra, the various species). Roonwal and Agarwal (1966) have given the methods of measurements of rodent body-parts and skull for taxonomic purposes.

Other studies are those on *Millardia* (V.C. Agarwal 1970), *Bandicota bengalensis* (V.C. Agarwal and Chakraborty 1976), *Tatera indica* (V.C. Agarwal and Chakraborty 1981 and R.K. Ghose and Chakraborty 1976) and *Golunda ellioti* (V.C. Agarwal and Chakraborty 1982). The taxonomy of oriental Sciuridae has been studied by Moore (1959, 1960), Moore and Tate (1965), V.C. Agarwal and Chakraborty (1975, 1979a, b), V.C. Agarwal and Bhattacharyya (1979), and Saha (1977a, b, Bhutan). The status of genus *Mus* and allies has been examined by Fry (1931), R. Gupta and Srivastava (1975), Marshall (1977, Asian species) and A.K. Mukherjee and Mandal (1981, West Bengal).

The regional rodent faunas have been studied by the following contributors :-

Jammu and Kashmir : S. Chakraborty (1983).

Himachal Pradesh : Mahajan and Mukherjee (1972, 1974, checklist).

Punjab : Bindra and Sagar (1975), M.L. Sood and Dilber (1971a, 1978), M.L. Sood and Guraya (1978) and M.L. Sood and Ubi (1975).

Uttar Pradesh : Sheikher et al. (1983, Muridae of Garhwal Himalayas, 5 species) and S.K. Jain (1975).

Rajasthan, including the Indian Desert : Biswas and Ghose (1968, new records), Ghose (1976, more new records), I. Prakash (1936, 1959c, 1963, 1974a, 1975a, n), Prakash and Mathur (1979), and Prakash and Rana (1970, 1972, 1973).

Madhya Pradesh : Hill (1958), A.P. Jain (1985, Mandsaur District), Khajuria and Ghosal (1981, Narbada Valley).

Goa V.C. Agarwal (1973).

Andhra Pradesh : V.C. Agarwal and Bhattacharyya (1976, Nagarjun Sagar), Y Chaturvedi (1974, also Nagarjun Sagar.), Mohana Rao (1977a, Tirupait, 1978, 1980).

Western Ghats : Tiwari et al. (1971).

West Bengal Ghose and Chakraborty (1983, flying squirrels, Darjeeling District) and Mandal (1981a, b).

Sikkim Ghose and Chakraborty (1983, flying squirrel) and Mandal (1982b).

Tripura V.C. Agarwal and Bhattacharyya (1975, 1977).

North-Eastern India (Assam, Manipur, Mizoram, etc.) Roonwal (1948, 1949b, 1950, Manipur), Ghose (1966, Mizoram), Kurup (1966, 1974, zoogeography), V.C. Agarwal 1980, Muridae) and Chauhan and Saxena (1982a, Mizoram).

Andaman and Nicobar Islands Y Chaturvedi (1966c, and new house rat; 1980, zoogeography and faunal affinity) and Saha (1980).

Bhutan S. Chakraborty (1975b) and Saha (1977a, b, 1979).

Nepal Biswas and Khajuria (1955, 1957, 1968), Bhatt (1970), V.C. Agarwal and Chakraborty (1971), Green (1981, Langtang National Park), D. Johnson et al, (1985) and Mitchell and Derksen (1976).

Burma Roonwal (1948, 1949a, b) and Davison (1982).

Sri Lanka Eisenberg and McKay (1970, checklist with keys).

Pakistan Siddiqi (1961, checklist), Taber et al. (1971, Lyallapur) and Roberts (1977).

Much of the rodent taxonomic work in India has been handicapped by a lack of the utilisation of proper collection techniques as regards traps, etc. and the paucity and preservation of abundant museum material complete with skins and skulls. As a result, identifications up to the subspecific levels and the study of geographical and other types of variations have seldom been posssible. It is to be hoped that future workers will ensure that the material collected is both abundant, well preserved and complete and is deposited in an institution (like the Zoological Survey of India) where long-term care and maintenance are ensured and the material is readily accessible to future workers.

Fossils :

Rodent fossils in India are rare. Recently, Gaur (1986) has described the fossil molar of *Rattus* sp. from the Pinjor formation of the Upper Siwalik in North India. Other murid fossils from the Siwaliks are those of the genera *Nesokia, Mus* and *Golunda.*

IV-MORPHOLOGY, HISTOLOGY AND CYTOLOGY

(A) Anatomy and Morphology

A comprehensive account of the anatomy and morphology of all systems of an Indian rodent is that by S.M. Das (1959) for the northern palm squirrel, *Funambulus pennanti.* Agarwal (1979a, b) has made a detailed study of the morphology of the skull of oriental rodents in relation to taxonomy and fossorial habit, while Roonwal and Agarwal (1966) have given the methods of body and skull measurements for taxonomical purposes. Malocclusion in rodent incisors has been discussed by Y Chaturvedi (1966b), and V.C. Agarwal (1966c) has studied the muscles of mastication in the gerbil *Meriones hurrianae.*

Arslam (1962) has described the structute of the penis in the squirrel *Funambulus pennanti.* Other anatomical studies are on the hyoid region of Indian gerbils (D.R. Sharma and Sivaram 1959), mandibles of the flying squirrels (B.B. Gupta 1971 a), hair structure in *Rattus rattus* and *Nesokia indica* (Hurter 1979), and the anatomy of the cardiac conducting system in *"Nesokia bandicota"* (? probably *Nesokia indica*) (Qayyum and Bhatnagar 1972). Kanwar (1962) has studied the morphology of the intestinal goblet cells in rats. The occurrence of the ventral marking gland has been mentioned by Prakash and Kumari (1977, several species), Idris (1981. *Gerbillus nanus indus*) and Rana and Jain (1981, *Gerbillus gleadowi*).

(B) Histology, Cytology, Histochemistry, Cytochemistry

In *Rattus rattus* P.V. Shah et al. (1974) have studied the histology of wound healing and repair in the liver of diabetic rats; S. Ghosh and Ghosh (1966) the histological changes in the nucleic acid constituents of nerve cells following the administration of librium; B.L. Gupta et al. (1960), the histochemistry of the ovary; and Kanwar (1962), the cytochemistry of the intestinal goblet cells. Qayyum and Bhatnagar (1972) have studied the neurohistology of the cardiac conducting system in *"Nesokia bandicota"* (? = probably *Nesokia indica*); Purwar the neurohistology (1972) of the intrinsic enervation of the pancreatic duct and the histochemistry (1977) of the nerve endings in the lung of *Rattus rattus rufescens;* and Kaul and Ramaswamy (1971) the cytology of the pituitary gland in *Meriones hurrianae.* R.C. Chaubey et al. (1978) have evaluated the micronucleus test in rodents.

The chromosomes, mitosis, etc. in several species have been studied in the folllowing species

Funambulus pennanti : V Chopra and Pai (1965), R.S. Mathur (1966, cytochemistry during spermatogenesis), and V.K. Sharma et al. (1970, DNA synthesis in sex chromosomes).

Funambulus palmarum : R.S. Mathur (1966, cytochemistry during spermatogenesis) and Satyaprakash and Aswathanarayana (1973, chromosomal dynamics).

Funambulus tristriatus : S.R.V Rao et al. (1973, chromosomes and their bearing on intrageneric relationships).

Tatera indica : S.R.V Rao et al. (1969, autoradiography of sex chromosomes).

Rattus rattus : Chaudhuri and Sethi (1970, the effect of intrauterine contraceptive devise on mitosis in uterus), Ray-Chaudhuri and Pathak (1970) and Rai-Chaudhuri et al. (1972, chromosomes), Aravinda Babu et al. (1975, banding patterns in chromosomes), Padmini et al. (1975, mitotic figures in albino rats) and Parida (1985, induction of anaphase bridge in haepatocytes).

Rattus blanfordi : S.R.V Rao and Lakhotia (1972, chromosomes).

Rattus gleadowi Satyaprakash and Aswathanarayana (1971, chromosomes in male their *"Millardia gleadowi"*).

Mus platythrix : Pathak (1970, karyotype).

Nesokia indica : Jhanwar et al. (1971, polymorphism in sex chromosomes).

Bandicota bengalensis : T Sharma et al. (1973, variation in heterochromatin in sex chromosomes).

V ECOLOGY, BIOLOGY AND BEHAVIOUR ETC.

Here a general account is provided; more details will be found below in the Account of Species. It is important to emphasise that a knowledge of the habits, habitats, food, breeding pattern, behaviour and population dynamics, are essential for the success of control operations. Excellent general account of the ecology of rodents will be found in Elton (1942, 1958).

Ecology :

Several rodents species, like squirrels, are diurnal in habits, but many others, such as rats, mice, bandicoots and porcupines, are nocturnal. Gerbils

may be either nocturnal (*Tatera indica*) or diurnal (*Meriones hurrianae*). Many species, e.g., several rats, mice, bandicoots and porcupines, are fossorial and live in burrows or restricted places such as crevices where they nest, while others live in open ground or are arboreal.

Some rodents adapt themselves to a wide variety of habitats while others are more restricted in their choice. These habitats have been discussed by Barnett and Prakash (1975) for species of economic importance. Sen (1975) has provided a geographical appraisal of typical rodent habitats. Ports are the favourite, recently-acquired locations of some species such as *Rattus norvegicus, Rattus rattus* and some bandicoots (*Nesokia* spp.) because of the abundance of available food in ships, godowns and sewers, as in Bombay (Deoras 1963-1966, Deoras and Bhatt 1981, Deoras and Mittal 1980, Deoras and Pradhan 1975), Calcutta (Seal 1966a, b, Seal and Banerji 1969). Aziz (1965) has reported the infestation of coal mines in Bihar by rodents. Roonwal (1949b) has discussed the preferences of various ecological habits, e.g. evergreen jungle, oak scrub, riverine meadow, etc., by several species of rodents in Manipur (NE India). The ecological preferences of various gerbils in the Indian Desert area of Western Rajasthan have been described in considerable detail by I. Prakash (1962, 1963, 1971b, 1972, 1974a, 1975a, b, n, Prakash, Gupta et al. 1971 and Prakash and Rana 1972, 1973). In Uttar Pradesh, A.S. Srivastava, Mathur and Bhadauria (1983) have studied the distribution pattern of rodents in different soils, and A.S. Srivastava and Gupta et al. (1971) the distribution of field rats in a more restricted area (the Kalyanpur Block of Kanpur District). S.K. Garg and Chandana (1981) have studied rodent distribution in relation to soil texture; and Sreenivasan (1973) their distribution in relation to vegetation types in Karnataka.

Some rodents (*Rattus rattus, Mus musculus*) are commensal with man and do considerable damage to food stuffs and other household goods; interspecific relationships among such species have been discussed by Urs et al. (1975).

Population changes :

The pioneer population studies on rodents, especially as regards plagues (explosions) and invasions are by Elton (1942, 1958). For a general account of rodent populations and migrations, also see Roonwal (1945, 1949a). Davis (1969) has given a general appraisal of rat populations. In North-Eastern India (Assam, Mizoram, etc.) dramatic population increases of *Rattus rattus* have been correlated with the periodical flowering of

bamboos (S.C. Seal, Ghosal and Bose 1951, A.K. Ghosh 1977); after eating the flowers, huge population of rats poured into rice fields, causing famine. Population explosions have also been recorded in groundnut fields in Gujarat by M.P. Shah (1979) and in parts of Uttar Pradesh by A.S. Srivastava and Bhadauria (1983). Mandal and Ghosh (1979, 1983) have examined the effect of floods on rodent populations at Singur in the Hoogli District of West Bengal, including the recovery time after the initial decline. Populations in the cyclone-affected areas of Andhra Pradesh have been studied by Mohana Rao (1978, 1980).

Changes in populations of rodents in the Indian Desert (Western Rajasthan) have been studied by Prakash (1962, 1975a, c, l, 1977b, 1981b), Prakash, Gupta et al. 1971, Prakash and Rana (1970, 1973) and Prakash, Teneja, and Purohit (1971). Population fluctuations of murids in fields in the Punjab have been studied by Bindra and Sagar (1971), M.L. Sood and Dilber (1977a, 1978) and M.L. Sood and Ubi (1975). Rat populations in Bombay have been examined by Deoras (1966c, 1969), and in Calcutta (especially in relation to the incidence of bubonic plague) by Seal (1961), Seal and Banerji (1969, 1981) and Seal and Bhattacharji (1961a, b).

Biology, breeding and food :

The biology of rodent species in various regions has been studied in considerable detail (summary of the economically important species in Barnett and Prakash 1975). The Punjab species have been studied in detail by Sagar and Bindra (1970, 1971), Bindra and Sagar (1968, 1975), M.L. Sood and Guraya (1978), Guraya and Gupta (1975); of Western Rajasthan (The Indian Desert) by Prakash (1960, 1964a, 1971a, 1977a), Prakash and Jain (1971c), Prakash, Jain and Purohit (1971), Prakash, Rana and Jain (1973) and Rana and Prakash (1984); of Uttar Pradesh by A.S. Srivastava (1968), A.S. Srivastava and Nigam (1975a, b), A.S. Srivastava, Tripathi and Awasthi (1971), and P.M. Nigam (1981a, b, 1982a, b, 1983); of Peninsular India by Mohana Rao (1975, 1977b, 1981) and Srihari and Rai (1984); of West Bengal by Spillet (1968, 1969a, b); and of Sind (Pakistan) by Fulk et al. (1979, 1981, rats in rice fields).

Breeding may be either seasonal or spread out more evenly through the year. In addition to those already mentioned, contributions to reproductive biology have also been made by I. Prakash (1975g), P.K. Ghosh and Taneja (1968), M.R.N. Prasad (1956, 1961), M.R.N. Prasad et al. (1966), Purohit et al. (1966), Seth and Prasad (1969), P.V Kumari and Khan (1984), Kaul

and Ramaswami (1969), Chauhan and Saxena (1982b, c, 1983), Mandal (1982a, d), Roonwal (1949b), Sud (1976), Dominic and Pandey (1979), and Srihari and Rai (1984).

While some rodents have distinct food preferences, others are omnivorous. The majority are herbivorous but throw in some amount of animal matter (both invertebrates such as alate termites and the smaller vertebrates such as small birds). One species, *Rattus manipulus,* in Manipur (N.E. india) feeds largely on earthworms which are cut up in small pieces, about a centimetre long, and swallowed, and the rat's stomach is full of such pieces (Roonwal 1949b). Odend'hal (1980) has reported *Rattus rattus* feeding on dying cattle affected with foot-and-mouth disease. Cannibalism is not uncommon, the young ones being especially victimised (P.D. Gupta and Agarwal 1968, Jain 1984; and others). Food preferences of various types have been reported by Asari (1975, varieties of tapioca in *Rattus* sp.), Krishnaswami and Chowhan (1957, insects as food of squirrels in Bihar), Roonwal (1949b, food preferences of several rodents in Manipur), and others. The food preferences of several species of rats and gerbils in the Indian Desert have been discussed by I. Prakash (1959a, b, 1969b, 1974a, 1975d, 1977a), I. Prakash, Purohit and Kametkar (1967), and Jain (1975a, b, 1981, 1984). For additives in baits, the preferences for vegetable oils (groundnut, gingeli, mustard and coconut), by gerbils and *Mus* in Haryana, have been studied by Pasahan and Sabhlok (1981, 4-5 per cent of groundnut oil is the most preferred).

The food habits and related behaviour patterns such as daily cycle, hoarding, etc. have also been studied by P.V. Kumari and Khan (1985), M.R.N. Prasad (1954), Sridhara (1978), Srihari and Sridhara (1979), A.S. Srivastava and Bhadauria (1982), Durairaj and Rao (1975) and R. Chakraborty and Chakraborty (1982).

Behaviour :

The behaviour of the rat, *Rattus rattus,* has been studied in considerable detail in the laboratory by Barnett (1975), While a handy summary of the behaviour patterns of rodents of economic importance in India has been provided by Barnett and Prakash (1975). Community structure has been discussed by Calhoun (1969). Patterns of behaviour in the Indian Desert have been studied by V.C. Agarwal (1967d), Fitzwater and Prakash (1969, 1973), I. Prakash (1962, 1974a, 1975n, 1981b), I. Prakash, Gupta et al. (1971), I. Prakash and Jain (1971a, c), I. Prakash, Kumbkarni and Krishnan (1965), I. Prakash and Ojha (1977), Rana, Prakash and Jain

(1975), Rana (1975), and Rana and Soni (1981). (For a pioneer study of this and other deserts, vide Buxton 1923.).

Among others who have contributed to behavioural studies are: Ganguli and Kaul (1962), Bharadwaj and Prakash (1980), Jackson (1966), Parrack (1966, 1969), Parrack and Thomas (1970), Raman and Soni (1970), Sagar and Bindra (1971), Sridhara et al. (1978-1979). A special aspect, the changes in behaviour of rodents during a solar eclipse, has been examined by Advani (1981) and A.K. Mukherjee et al. (1982).

VI. PHYSIOLOGY AND GENETICS

While the physiology of the common rat has been well studied (the albino variety of the rodent being the animal of choice for applied medical research), work in Indian on this and other species has been both limited and cursory.

Physiological adaptations to desert life have received considerable attention, e.g., by P.K. Ghosh (1975a, 1977), P.K. Ghosh and Gaur (1966, salt tolerance to water requirements), P.K. Ghosh, Goyal and Prakash (1977, metabolism and ecophysiology), P.K. Ghosh, Purohit and Prakash (1962, effects of prolonged water deprivation), and Goyal, Ghosh and Prakash (1979, physiological adaptive mechanisms; 1980, 1981, body fat in relation to basal metabolic rate). Schmid-Nielsen (1964) has given a general discussion on the physiology of desert rodents.

Some work had also been done on reproductive physiology (including aspects of family planning), e.g, by Bhattacharya and Pal (1974, effects of plant estrogens on the growth of mammary glands in mice), Bodhankar et al. (1974, the antifertility effect of plants on early pregnancy in albino rats), Chinoy and Seethalakshmi (1977, effect of induced blindness on the reproductive physiology of male albino rats), Chinoy and Sheth (1977a, b, c, effects of inanition, protein malnutrition, ascorbic acid and some drugs on the activity of accessory sex glands in male rats), R.P. Das et al. (1977, effects of centchroman on the reproductive system, adrenal gland and liver function in male rats), Dominic (1965-1976, effect of pheromones on fertility in mice), Dominic and Pandey (1979, suppression of oestrus in *Mus booduga* by treatment with antiandrogen), Garyali and Saxena (1975, reproductive physiology and fertility control in male *Nesokia indica*), Madhawa Raj and Moudgal (1970, harmonal control of gestation in rats), Maneckjee et al. (1977, effect of exogenous gonadotropins on overies during

lactation in rats), Pradhan and Viswanathan (1984, course of blood circulation in the mammary glands of bandicoots), Sarda et al. (1977, vaginal smear patterns and blood progesterone levels in rats), Sasidharan (1981, effect of steroid hormones on the reproductive system of male *Tatera indica*), M. Singh 1975, interaction between protein and folate status on cellular development in foetal rats), and Vijaykumar and Rao (1976, effect of cortisone acetate on the testes and accessory organs in albino rats). Embryonic sex ratios in bandicoots have been studied by Pradhan (1980b) and Pradhan and Viswanathan (1980), while the relation between sex ratios and breeding season in field rats has been examined by Pradhan (1980c). The biochemistry of ageing has been studied by Kanungo and associates (1965-1985, vide infra, *Rattus rattus*).

Other physiological studies are by Anand and Broback (1951a, b, location of feeding centre in the hypothalamus in rats, Ambadker and Vyas (1975, effect of castration on the lipid metabolism of preputial glands in male rats), Azhar et al. (1974, hydrolic enzymes in intestinal caecum in infested rats), Chandrahas (1978, seasonal changes in body weight), P.N. Das et al. (1960, effects of gamma radiation on nitrogenous end-products in the urine of albino rats), Deoras and Chaturvedi (1971a, duration of oestrus cycle in Bombay rats), J.C. George and Iype (1961, lipase activity of heart muscle in young rats), J.C. George and Susheila (1966, effect of starvation on some physiological activities in the rat diaphragm), P.K. Ghosh, Gaur and Taneja (1969, adrenal responses to varying available floor space in *Meriones hurrianae),* Mathur and Johnson (1982-1986b, effect of natural helminthic infections on certain physiological activities in the house rat), Mitral et al. (1962, effect of X-irradiation on the adrenals of albino rats), I.P. Saxena (1971, electrophoresis of blood system in the house rat), P.P. Sood and Tewari (1970, distribution of succinic dehydrogenase in the olfactory bulb of the house mouse), and Srihari and Shakunthala (1979, heamatological changes in *Bandicota bengalensis* induced by rodenticide treatment). The role of body odours and scent-marking has been studied by Idris (1981, 1982), Idris and Prakash (1983), M. Krishnamurthy (1981, 1982) and S. Kumari and Prakash (1979-1982).

Few genetical studies have been made on Indian rodents. Price-Evans and Sheppard (1966) have studied the genetics of resistance to anticoagulant in *Rattus norvegicus;* V. Banerjee (1971), the genetics of aggression induced by isolation in mice; Greaves, Rehman et al. (1976) the inheritance of resistance to warfarin in the house rat *Rattus rattus;* and Pradhan and Mithel (1981), the genetical control of the white patch in some rodents. Mutation

and other genetical aspects in rats have been studied by P.S. Chawhan et al. (1973, 1984), Arayindakshan et al. (1975, 1985) and R.C. Chaubey et al. (1978).

VII. PARASITES OF RODENTS

Rodents are subject to parasitisism, both external and internal, by a wide variety of organisms such as bacteria, protozoa, arthropods (ticks, mites and insects) and helminthic worms. Some of these parasites cause disease and death, which may spread to man (vide infra, the section on Rodents and Disease; and also the brief discussions by Anantaraman 1969, and Barnett and Prakash 1975).

(A) Ectoparasites

Haas and Tomich (1966) have given a useful account of the survey methods for rodent ectoparasites.

Ticks and mites (Acarina) :

These have been studied by S.M. Das and Sharma (1970, ticks in Kashmir), H.N. Kaul et al. (1978, Rajasthan), Kulkarni (1978), Kulkarni et al. (1978) and Mishra et al. (1977) the last three, recording trombiculid mites in the Western Ghats), P.R. Rao et al. (1978, the Himalayan belt), U. Rao (1971), Roonwal (1949a, trombiculid mites in Manipur and Western Burma), S.P. Srivastava and Wattal (1970, Dharmshala area, Himachal Pradesh), B.N. Varma (1967, Jammu-Sialkot-Lahore belt), R.N. Varma and Mahadevan (1970, 1972a, b, ticks and mites in the Eastern Himalayas), and Wattal et al. (1967, mites in Delhi area). In Pakistan ticks harbouring viruses have been recorded from the vole *Alticola roylei* at high altitudes and the gerbil *Tatera indica* by Begum, Wisseman and Traub (1970).

Insects :

Fleas (Siphonaptera; Aphaniptera of some authors) and sucking-lice (Sippunculata; Anoplura of some authors) have been reported from rodents by Chandrahas and Krishnaswami (1970, fleas on wild rodents, South India), Chaturvedi i and Deoras (1972, fleas on *Rattus rattus*), Deoras and Chaturvedi (1971b, fleas on Bombay rats), Mishra and Bhatt (1972, lice *Hoplopleura* spp.), Mishra, Dhanda and Kulkarni (1977) and Mishra and Kaul (1973) (the last three, Anoplura), R.S. Prasad (1971, 1973, methods of assessing host-flea relation-ships in rats), Roonwal and Nataraj (1946, two

species of lice from the squirrel *Funambulus pennanti*), S.P. Srivastava and Wattal (1970, Himachal Pradesh), and Walton and Maung Tun (1978, Fleas, Burma).

(B) Endoparasites

Bacteria, etc. :

The most well known is the bacterium *Pasteurella pestis* which is the pathogen causing the once dreaded bubonic plague in rats and man. The pathogen is transmitted from one primary host-rodent to another, and also to man, through the agency of fleas. The house rat, *Rattus rattus,* is the most common host, but other rodents such as *Rattus norvegicus, Bandicoota bengalensis* and probably gerbils, are also subject to plague.

Bacteria of the genus *Salmonella* are parasitic in rodents in which they cause a fatal disease. Their use as a means of biological control of rodents has been suggested, but there are strong reasons to avoid this (Woodzicki 1973 and I. Prakash 1974b) first because its efficacy has never been proved satisfactorily, and secondly because the organism causes a dangerous illness, salmonellosis (a kind of food poisoning) in man. Rickettsiae (which cause scrub typhus), and a number of other organisms are also harboured by rodents.

Protozoa :

The intestinal flagellates of the common house rat, *Rattus rattus,* have been investigated by Navarathnam (1970).

Helminthic worms :

Considerable work has been done on the helminths of Indian rodents, especially of the Indian Desert.

Trematoda : The trematode parasites have been studied by S. Johnson and Singhvi (1977, checklist, Rajasthan Desert), Nama and Parihar (1975, in *Rattus rattus,* 1981, in *Tatera indica*) and A. Parihar and Nama (1978b, in *Funambulus pennanti*).

Cestoda : The cestode parasites have been investigated by S. Johnson and Singhvi (1977, checklist, Rajasthan Desert), Nama (1974a, b, c, 1975), Nama and Khichi (1975, in *Rattus rattus*), Nana and Parihar (1976, in *Rattus rattus,* 1981, in *Tatera indica*), A. Parihar and Nama (1977b, c, *Tatera indica,* 1978a, in *Funambulus pennanti,* 1980 in several rodents), Reddy and Suvarnakumari (1971, the biology of *Echinococcus granul-*

in rats and mice, the causative agent of hydatid disease in man and animals in South India), Singhvi and Johnson (1976, 1978a, c, 1980c, 1982, all in *Rattus rattus*), S.R. Srivastava (1971, hymenolepis infection in man caused through rats), and Wason and Johnson (1977, in *Tatera indica*).

Nematoda : The nematode parasites have been investigated by S. Johnson (1967-1979, in several rodents of the Indian Desert), S. Johnson and Singhvi (1977, checklist of the desert area), Nama and Jain (1972, in *Funambulus pennanti*), Nama and Parihar (1976, in *Rattus rattus,* 1981 and 1982, in *Tatera indica*), Nama and Saxena (1974, in *Rattus rattus*), A. Parihar and Nama (1977a, b, 1978 a,c,d, 1979, 1980, *Funambulus Pennanti*), A. Saxena and Nama (1977a-c, house rat) and Singhvi and Johnson (1975, 1977, 1977b, 1978b,c,d, 1979a-d, 1980a,b,c, 1981a,b, 1982, 1983, 1985, 1986, all in *Rattus rattus*).

VIII. RODENTS AND DISEASE

Rodents are subject to several communicable diseases; they also act as reservoirs of several diseases and as hosts for the vectors (fleas, sucking-lice, ticks and larval mites), which carry the pathogenic organisms, e.g., protozoa, spirochaetes, bacteria, rickettsiae, bartonellae viruses and fungi, which cause several human diseases such as plague, peichmaniasis, salmonellosis, murine typhus, scrub typhus (tsustugamuchi disease), Kyasanur forest disease, sandfly fever, tapeworm infections, etc. (for a discussion, vide Baltazard 1966, Howard 1968, Pandit 1970 and J.K. Bhatnagar 1971).

Bubonic plague

A comprehensive discussion on all aspects of plague has been provided by Pallitzer (1954). Although plague no longer occurs in severe epidemics, endemic pockets exist, and its epidemiology, especially in relation to rodent and flea populations, has been under surveillance in many parts of India by the following workers : J.K. Bhatnagar (1969) and Prasad (1965, epidemiology, Uttar Pradesh), Brooks et al. (1977, Burma), Chandrahas (1975) and Chandrahas et al. (1974, epidemiology, South India), Chandrahas and Krishnaswami (1971, flea fauna, some plague areas in South India), Deoras, Dhamanaskar and Bhatt (1971, mice rearing for plague study), Gowda (1969, rodent control in plague areas in Kolar District, Karnataka), A.K. Krishnaswami et al. (1963, also the Kolar District, Karnataka), A.K. Krishnaswami et al. (1970, 1972, serological survey of rodents in South India plague focus), Nimbkar and Deoras (1969) and Nimbkar et al. (1971, 1973, susceptibility of rats to plague infection), Ramakrishnan

(1965, current status of plague in India), Sant et al. (1970, epidemiology, Thana District, Maharashtra), Seal (1960a, b, epidemiology in India and rodent and flea populations in Calcutta and vicinity; 1961, the role of domestic rodents), Seal and Banerji (1969) and Seal and Bhattacharji (1954, 1961a, b, rat and flea populations in Calcutta), Seal and Patnaik (1963, plague in Madras), and Suri (1975, rodents and plague, India).

Kyasanur forest disease (KFD) :

The virus-caused Kyasanur forest disease in South India has come into prominence in recent years. It is believed to be transmitted by rodents and other animals. Observations have been made by Nayar (1972, histological changes in mice infected with the disease), Rajagopalan (1969, role of rodents), Sreenivasana (1973, distribution of rodents in relation to vegetation in the Kyasanur forest disease in Karnataka), and Webb (1965, the concerned virus in three species of rodents). S.N. Ghosh and Rajagopalan (1973) has recorded encephalomyocarditis virsu activity in *Mus booduga* in a KFD area in Karnataka.

Scrub typhus (tsutsugamuchi disease) :

This rickettsia-caused virus is widespread, from South Asia east to Wahan, New Guinea and Australia, and is believed to be spread through rodents (as reservoirs) with larval trombiculid mites as vectors. Some work has been done in India by Audie (1947, epidemiology), Mackie (1946, epidemiology, Assam and Burma), Roonwal (1949b, rodents and mite infestation in Manipur and Western Burma), and R.N. Varma and Mahadevan (1972a, b, 1973, epidemiology, vector potential of trombiculid mites, Eastern Himalayas).

Other diseases :

Choudhary et al (1971) have provided serological evidence of *Coxiella brunetii* infection in domestic rodents. The biology of the cestode worm *Echinococcus granulosus,* which causes the hydatid disease in man and animals, has been studied by Reddy and Suvarnakumari (1971) in rats and mice in South India; and S.R. Srivastava (1971) has discussed the infection (hymenolepiasis) caused in man by another cestode worm *hymenolepis* through the rat. M.I.D. Sharma et al. (1973 a, b) and Kalra and Lewis (1975) have studied the epidemiology of leichmaniasis. A tick-borne virus has been isolated from rodents (the vole *Alticola roylei* and the gerbil *Tatera indica*) in Pakistan by Begum, Wisseman and Casala (1970a, b, c.) and Begum, Wisseman and Traub (1970).

IX. RODENT CONTROL

Much work has been done on rodent control in India and elsewhere. The methods vary widely, from the use of mechanical devices, such as trapping, fencing, etc., to the utilisation of a variety of chemicals, both organic and inorganic, for different purposes, e.g., fumigation and poison-baiting, etc. Mechanical methods have a limited utility but can be employed in special cases. For practical purposes, the use of chemicals in the method of choice. Fumigation with cyanogas is successful in some cases but has the obvious disadvantages of being hazardous, difficult to use in burrows with multiple openings all of which cannot be plugged and so result in leakage, and the need for using costly equipment and trained operators. The choice is thus confined to the use of stomach poisons, including anticoagulants such as warfarin; and, in future, perhaps on chemosterilants. The chemicals that have been used with success are: alphanaphylthiourea (anta), aluminium phosphide, ammonium fluoride, arsenious oxide, barium carbonate, fluoroacetamide, lead arsenate, soidum fluoroacetate, strychnine alkaloid, thallium sulphate, warfarin and zinc phosphide. Grains (wheat, millet, etc.) and wild berries soaked in the chemical are used as bait which is broadcast near the habitats (burrows, crevices, etc.) of the rodent concerned. Prebaiting by the untreated carrier for two or three days is necessary, followed by a single exposure to the poisoned bait, after which the victims usually develops bait shyness.

The Indian work especially with rodenticides, has been aptly summarised by Majumdar, Krishnakumari and Muktabai (1969), Fitzwater and Prakash (1973) and Barnett and Prakash (1975). Since then, much work has been done on various aspects of rodent damage, their role in disease, and the methods of control by a variety of rodenticides. A considerable body of literature is thus available, but it is largely repetitive, of a routine nature, and difficult to classify. The references are, therefore, listed below alphabetically for ease of consultation and the reader is adivsed to group them according to his need :

Advani and Mathur (1979, 1981, 1982b), Ahmad and Prashad (1983), Ahuja (1975), Anonymous (1976-1983); Apte (1975), Arora and Doharey (1979), Arora et al. (1978, 1979), S.N. Banerji (1975), Batra (1969), Bayne et al. (1971), Bharadwaj and Khan (1977, 1980), Bharadwaj and Prakash (1983), Bhat (1978a, b, 1981), R.K. Bhatnagar and Butani (1976), R.K. Bhatnagar et al. (1981 1985a, b), Bindra and Sagar (1971,1975), Brooks and Htun (1978), Brooks et al. (1980), chandna (1981, 1982), Chandna et

al. (1981), Chandrahas and Samuel (1980), Chandurkar et al. (1972), Chatterjee (1971), G.C. Chaturvedi (1974, 1975c-d, 1978), G.C. Chaturvedi and Patel (1977), G.C. Chaturvedi et al.(1970, 1972, 1975, 1978a, b), Chitty (1954), G. Chopra and Sood (1982, 1983), G. Chopra et al. (1982-1983), Christopher et al. (1982-1984), Cowan (1978), Cowan et al. (1977), M.S. Das (1975), Deoras (1966, a, b, 1971, 1972), Deoras et al. (1972), Dhall (1975), Dharmaraju (1975), diwakar et al. (1984), Doharey et al. (1980), Drummond (1971), Durairaj and Guruprasad (1975b), Dykstra (1966, 1968), Fitzwater and Prakash (1973), Food and Agricultural Organisation (1970, 1973, 1977), Frantz (1975, 1976), Freeman (1954), Gandhle et al. (1982), Ganguli and Kaul (1962), D.N. Garg and Agarwal (1963), N.K. Garg and Bharadwaj (1978), Garrison (1980), A.K. Ghosh (1980), P.K. Ghosh (1975b, c), A.S. Gill and Srinath (1975), Girish and Agarwal (1979a, b), Girish and Ali (1979), Girish and Nishad (1979), Girish and Sagalgile (1979), Girish and Singh (1979), Girish and Sonelal (1979), Girish et al. (1972, 1975), Gokhale (1975), Greaves et al. (1977), B.B. Gupta (1971a, b), B.K. Gupta (1983), K.M. Gupta et al. (1971), R.K. Gupta and Prakash (1978), Guruprasad and Srihari (1978), Harris (1975), Howard and Marsh (1975), Htun and Brooks (1979), Jackson (1966, 1979), A.P. Jain (1975b, 1980a, b), A.P. Jain and Das (1980), A.P. Jain, Prakash and Rana (1975b), S.K. Jain (1975), Jhala (1979), Jhala et al. (1984), Joshi (1975), Jotwani and Berry (1971), Kalla (1975), Karapulkar and Navelkar (1979), Kidavu and Koya (1955), Krishnakumari (1975), Krishnakumari and Majumder (1969), Krishnakumari et al. (1971, 1978, 1979), B.S. Krishnamurthy (1971), K. Krishnamurthy (1971, 1975a-c), K. Krishnamurthy and Agarwal (1975), K. Krishnamurthy and Singh (1967), K. Krishnamurthy et al. (1967, 1968, 1971), Lal (1975), Madhwa Raj and Moudgal (1970), Madsen (1975a, b), Majumder (1970, 1971), Majumder et al. (1964, 1969), Malhotra (1975), Manekar and Shroff (1975), Manj (1977), H.S. Mann (1975), Marsh and Howard (1976, 1977), R.P. Mathur (1978, 1980), R.P. Mathur and Prakash (1980a, b, 1981), Y.K. Mathur et al. (1983), Mehra (1971), Mohana Rao 1975, 1982), Mohana Rao and Purushotham (1980), Mohana Rao and Singh (1983), Mohana Rao and Swami (1978), R. Mukherjee and Jain (1979), Muktha Bai (1975, 1979a, b, 1980, 1983), Muktha Bai and Krishnakumari (1975), Muktha Bai (1971, 1978, 1979, 1981), Muralidhara et al. (1975), Muthana (1975), Natarajan (1975), B.S. Nigam and Perti (1971), P.M. Nigam and Bhadauria (1982), Ojha (1978), Pahawa and Doharey (1980), Pahawa et al. (1981, 1982), Parpia (1971), Parshad (1986), Parshad et al. (1984), Patil

and Ghorpade (1982), Paur and Perti (1971), Perraju and Rao (1971), Peswani et al. (1975), Pingale (1966, 1969, 1971, 1979a, b), Pingale et al. (1967), Pradhan (1975, 1980a), I. Prakash (1964a, b, 1969a, 1971b, c, 1972, 1975b, e, f, h, i, m, 1976, 1977b, 1978, 1979, 1981a), I. Prakash, Fitzwater et al. (1969), I. Prakash and Jain (1970, 1971a, b, c,), I. Prakash and Kumbkarni (1963), I. Prakash, Kumbkarni et al. (1965), I. Prakash and Mathur (1977), I. Prakash and Ojha (1977), I. Prakash, Rana and Jain (1977, 1978), I. Prakash, Rana and Mathur (1977), I. Prakash, Taneja and Purohit (1971), O. Prakash and Avasthy (1980), Prashad et al. (1984, Price-Evans and Sheppard (1966), Qadiuddin (1954), Raghuramiah (1975), Rai (1982, 1983, 1984a, b, c,), C. Ramakrishnan et al. (1966), L. Ramakrishnan et al. (1975), Ramana and Sood (1980a), Rana (1975, 1979a, b), Rana and Jain (1978), Rana and Mathur (1981), Rana, Prakash and Jain (1975), Ranganathan (1979, 1981, 1982), M.S. Rao et al. (1975), N.S. Rao (1975), Redfern and Gill (1978), Redfern et al. (1976), Renupurkar and Bhatt (1975), Renupurkar, Chaturvedi et al. (1973), Renupurkar and Deoras (1975), Rizvi et al. (1980, 1981), Rowe and Redfern (1966), Roy (1974), Sabhlok and Pashan (1982), Sagar and Batth (1971), Savarte and Hayes (1980), K.D. Saxena (1963), Y Saxena and Sarma (1981), Y Saxena and Singh (1985), D.R. Shah and Subiah (1978), Shamsuddin and Koya (1983a, b, 1984), Shankunthala and Durairaj (1975), S.N. Sharma (1975), Sheikher and Ahmad (1986), Shetty (1967), Siddiqui and Khan (1984), C. Singh and Singh (1980a, b), H. Singh (1951), K. Singh and Ojha (1978), R. Singh and Saxena (1984), S. Singh (1969, 1976), S.M. Singh et al. (1965), Singhal (1971), Sinha and Ram (1963), Soni (1978, 1981), Soni and Jain (1985), Soni, Jain, and Soni (1984), Soni and Prakash (1981, 1983, 1984), M.L. Sood and Dilber (1977b), M.L. Sood and Gill (1978, 1980), M.L. Sood, Gill and Rangla (1978), N.K. Sood and Rathore (1971), Southern (1954), Spillot (1968), Sridhara and Krishnamoorthy (1978a, b, 1979), Sridhara and Srihari (1978a, b, 1979a) Srihari and Sridhara (1978a), Srinath (1975, 1977), Srinevasalu et al. (1971), A.S. Srivastava (1968, 1969, 1971, 1975), A.S. Srivastava, K.P. Mathur et al. (1971), A.S. Srivastava, Mathur and Bhadauria (1978a, b, 1979a, b, c), A.S. Srivastava, Y.K. Mathur et al. (1980), A.S. Srivastava and Nigam (1975c), A.S. Srivastava and Pandya (1971), A.S. Srivastava, Singh et al. (1971), A.S. Srivastava, Tripathi et al. (1971), P.K. Srivastava and Garg (1982), Subiah (1978a, b, c, 1979, 1983), Subiah and Mishra (1980), Thaker (1975), Trehan (1952), Tripathi and Shukla (1971), Urs (1975), Vaidyanathan (1963), Varadarajan (1975), B.K. Varma et al. (1978),

M.S. Varma (1971), S.S. Varma (1975), Vyas et al. (1985), Whitaker (1979), World Health Organization (1974), Yadav (1975).

X. ACCOUNT OF VARIOUS SPECIES

Apart from the review of recent advances in general topics as given above, it is useful also to give an account of various species, which can conveniently be grouped in two categories, viz., those of economic importance and the remainder.

(A) Rodents of Economic Importance

Of some 130 species of rodents known from the Indian Region, hardly a dozen or so have been regarded as of economic importance. All of them are associated with man in one way or another, and some are commensal. Their economic importance lies mainly in the damage they do to agricultural crops in the field and in storage, to household goods such as food, both cooked and uncooked, and paper records, and the part they play in the transmission of diseases such as bubonic plague, scrub typhus, etc., by acting as reservoirs and as primary hosts of disease - carrying vectors. Barnett and Prakash (1975) have provided a useful summary of these species of which the majority have a localised distribution but three are cosmopolitan. Most of the work done in recent years is inevitably confined to these species, to the neglect of the others, in some respects more interesting rodents. The economically important species are briefly dealt with below.

Family SCIURIDAE

1. **Funambulus pennanti** Wroughton

(The Northern Palm Squirrel of Five-striped Squirrel)

North India, pakistan, Nepal; probably Iran; Y. Chaturvedi (1966a) records it from the Andaman Islands in the Bay of Bengal. (In Peninsular India it is replaced by *F. palmarum*.). Mostly arboreal and found near human habitations. Diurnal, Breeding may be seasonal or throughout the year. Causes severe damage to fruits and vegetables in orchards and gardens.

Its biology and habits have been studied by Banerji (1955, 1957), Agarwal (1965a), M.R.N. Prasad et al. (1966), Purohit et al. (1966), Seth and Prasad (1969), Khan and Khan (1980, food preference), and Bhat (1981). P.D. Gupta and Agarwal (1968) have reported cannibalism.

S.M. Das (1959) has studied its morphology in considerable detail. Various aspects of its cytology have been discussed by V. Chopra and Pai (1965, chromosomes), R.S. Mathur (1966, spermatogenesis) and V.K. Sharma et al. (1970, sex chromosomes). Prakash and Kametkar (1969) have studied its body weight - age relationship.

The helminth parasites have been studied by several authors: S. Johnson (1967, a new nematode), Nama (1974b, 1975, cestodes), Nama and Jain (1972, nematodes), and Parihar and Nama (1978a-d, 1979, several helminths). Roonwal and Nataraj (1946) report two body lice (Anoplura) as ectoparasites. R.P. Mathur and Prakash (1980b) describe the use of an anticogulant for control.

2. **Funambulus palmarum** (Linnaeus)

(The Southern Palm Squirrel)

Peninsular India and Sri Lanka. Biology, habit and economic importance about the same as for *F. pennanti* which it replaces in the south. Little work has been done on this species. Satyaprakash and Aswathanarayana (1973) have studied the chromosomal dynamics and R.S. Mathur (1966) the cytochemistry of spermatogenesis.

Family HYSTRICIDAE

3. **Hytrix indica** Kerr

(The indian Crested Porcupine)

Widespread. Southern U.S.S.R., West Asia to India and Sri Lanka. Nocturnal and terrestrial; digs burrows. Litters from March to December, with probably two peaks. Is destructive to vegetables, especially tubers such as potatoes, etc. which it digs for food; also damages forest trees by girdling them.

Its biology, etc. have been studied by Roonwal (1949b, Manipur, Northeastern India), Taber et al. (1967, Pakistan), Prakash, Gupta, Jain and Rana (1971, the Indian Desert, Western Rajasthan), and R.S. Mathur (1966, spermatogenesis).

Family MURIDAE

4. **Tatera indica** (Hardwicke)

(The Indian Gerbil or Antelope-rat)

Iran to India; Sri Lanka. Nocturnal. Lives in burrows. Shows wide adaptability as to habitat and occurs in all sorts of situations, including lanes

in small towns. Breeding may occur throughout the year or may be seasonal.

It is one of the better studied species. Mandal and Sarkar (1984) record its occurrence in West Bengal. Agarwal and Chakraborty (1981) have examined its geographical variation, and R.K. Ghose and Chakraborty (1976) its taxonomic status in Madhya Pradesh; Prakash (1975 l) and Prakash and Rana (1970) have reported on its distribution in the Indian Desert. The autradiography of the sex chromosomes has been studied by S.R.V. Rao et al. (1969).

Its habits, ecology and biology have been studied by various authors: Murugesam and Jayapaul (1972), G.C. Chaturvedi (1971, burrows), Chandrahas and Krishnaswamy (1974, in Kolar District, Karnataka), C.M. George et al. (1982), P.K. Ghosh and Taneja (1968, oestrus cycle), P.V. Kumari and Khan (1984, parturition), Prakash, Jain and Purohit (1971, breeding and postnatal development), Sagar and Bindra (1970, breeding habits), Sasidharan (1981, effect of steroid hormones on reproduction) and Jain (1970, adrenal weight and pregnancy).

Food habits have been studied by P.V. Kumari and Khan (1985, daily food cycle), M.R.N. Prasad (1954, 1956, 1961, food habits and reproduction), Srihari and Sridhara (1979, hoarding behaviour), Prakash (1969b). Mann (1977a) found it eating winged termites, while Saini and Prashad (1968) reported that it occasionally ate a bird (the grey quail) in the laboratory.

Fulk et al. (1979) have followed its movements by telemetry. Its body odours have been studied by Idris (1982) and conspecific odours by S. Kumari and Prakash (1979), and Idris and Prakash (1982, 1983, 1986). Jain (1971) has examined its body weight-age relationship; Jain and Prakash (1981) eye lens-age relationship; P.V. Kumari and Khan (1983) the sounds produced by it; and Srihari and Shakunthala (1978) its haematology.

The helminth parasites have been studied by Johnson (1969b,c, 1973, 1975, nematodes, etc.), Wason and Johnson (1978, cestodes) and Nama and Parihar (1981, 1982, several groups).

Prakash and Jain (1971a) and Prakash and Ojha (1977) have recorded its bait shyness and aversion to poison baits, while P.M. Nigam and Bhadauria (1982) found that cadmium chromide is fatal to it. For additives in baits, Pasahan and Sabhlok (1981) found that 4-5 per cent concentration of groundnut oil is preferred over other vegetable oils. Parshad (1986) has reported on the evaluation of some rodenticides.

5. **Meriones hurrianae** (Jerdon)

(The Indian Desert Gerbil)

Iran, Pakistan, Western India (Punjab, Haryana, western Rajasthan, northern Gujarat). Diurnal. Lives in burrows. Like *Tatera indica* it occupies as wide variety of habitats. Breeding occurs throughout the year. Is highly destructive to agricultural crops, vegetables, etc. A well studied species.

Agarwal (1967a) has studied the muscles of mastication, and Prakash (1962, 1975l) has given its distribution in the Indian Desert. Several authors have studied its biology and ecology, especially in the desert zone of Western Rajasthan: Agarwal (1967d), Fitzwater and Prakash (1969, burrows and behaviour), Prakash, Purohit and Kametkar (1967, food), Prakash (1969b, food habits), Prakash (1981b), G.C. Chaturvedi (1971, burrows), and Ganguly and Kaul (1962, behaviour). Population variation has been studied by Prakash, Gupta et al. (1971), and Prakash, Taneja and Purohit (1971). Reproductive biology has been studied by Kaul and Ramaswamy (1969), and P.K. Ghosh and Taneja (1968, oestrus cycle), and water and salt physiology by Advani and Prakash (1980), P.K. Ghosh and Gaur (1966, salt balance in desert environment) and P.K. Ghosh, Purohit and Prakash (1962, effect of water deprivation). Its odours and scent-marking behaviour have been examined by S. Kumari and Prakash (1980a, b, 1981a-c, 1982) and Prakash and Kumari (1979), adrenal response to floor space by P.K. Ghosh, Gaur and Taneja (1969), and the cytology of the pituitary gland by Kaul and Ramaswami (1971). Some aspects of its physiology, etc. have been studied by Raizaday and Mathur (1981, histopathology of the ovary in relation to hypervitimasosis (A), Sarin and Saxena (1982, effect of two interperitonially administered organophosphorus insecticides on body weight and relative organ weight in males), and Dixit et al. (1982, testicular dysfunction by the administration of chloropropanes and cyclohexanol derivatives).

Its poison shyness has been examined by Ojha (1968) and various aspects of eco-toxicology by Prakash (1971, 1972), Prakash and Kumbkarni (1963), Prakash, Kumbkarni and Krishnan (1965) and Prakash, Taneja and Purohit (1971). Methods of control in the Indian Desert have been studied by Prakash, Fitzwater and Jain (1970) and Prakash, Soni and Mathur (1977). For additives in baits, preference of 4-5 per cent concentration of groundnut oil over other vegetable oils has been reported by Pasahan and Sabhlok (1981). Parshad (1986) has evaluated some rodenticides.

6. **Rattus rattus** (Linnaeus)

(The Common House Rat)

Almost cosmopolitan, but rare or absent in very cold regions. Nocturnal. Lives in various situations, e. g., in burrows, under roof thatchings, on coconut palms, in houses; is commensal with man, but also found wild. Breeds throughout the year but may have seasonal peaks. Is highly destructive, especially feeding on grains, vegetables, cooked food, coconuts, etc., but is sometimes facultatively insectivorous. Also serves as a host to various disease-carrying vectors. A well studied species; has numerous subspecies.

Some aspects of its taxonomic status have been studied by Tiwari et al. (1970), and geographical variation in Manipur (NE India) in the subspecies *R. r. bullocki* by Roonwal and Guha-Roy (1968). Its European form (the black rat, *Rattus rattus rattus*) is now well established in Bombay (H.S. Pradhan and Hemkar 1986). The structure of the hairs has been examined by Hurter (1979) and the chromosomes by Raman and Sharma (1972) and Satyaprakash and Krishnamurthy (1973). The neurohistology of the pancreatic duct has been studied by Purwar (1972), of the aortic arch by S. Kumar and Rai (1984), and the histochemistry of the nerve endings in lungs by Purwar (1977). The occurrence of melanism has been reported by Bhattacharyya (1971), and mutation and other genetical aspects examined by Aravindakshan et al. (1975) and R.S. Chauhan et al. (1975).

Considerable work has been done on its physiology. The biochemistry of ageing has been studied by several workers, e.g., Kanungo (1980, summary), Kanungo and Singh (1965), S.N. Singh and Kanungo (1968), Kanungo and Gandhi (1972), Moudgil and Kanungo (1973), Kanungo et al. (1975), James and Kanungo (1978), Chainy and Kanungo (1978), Thakur and Kanungo (1978), Suharkar and Kanungo (1983), M.M. Chaturvedi and Kanungo (1985a, b) and Hanjan and Talwar (1975). A 'feeding centre' has been located in the hypothalamus by Anand and Broback (1951a, b), while Gopal and Indira (1983) have examined the influence of the 'satiety centre' on temperature rhythm. Revathy et al. (1982) have studied the effect of juvenile hormone analogues on the rate of heart beat and liver histology, I. Gupta et al. (1982) the fertility regulation in males by flower extracts of some plants, and Pandian et al. (1975) and Hanjan and Talwar (1975) the effect of growth hormones. The physiology of ovariectomised rats has been examined by S.K. Sharma and Talwar (1970) and K.N. Rao and Talwar (1972), and the effect of low dose X-irradiation by V.C. Shah et al. (1976).

Subha Reddy et al. (1969) have reported on the inhibitory effect of enzymes from tuberculosis bacillus on the Yoshida sarcoma, Doctor et al. (1986) on the influence of oral lead acetate on serum transminases and alkaline phosphastase. Some aspects of physiology have also been studied by Mehrotra and Dauterman (1965, brain physiology), Katiyar et al. (1985) and S.V.S. Rana and Tayal (1986).

Its biology, ecology and population dynamics have been examined by several authors, e.g. Deoras (1963-1968) and Deoras et al. (1978-1980, in Bombay); K. Krishnamurthy, Ramasivan and Uniyal (1971, population flux and breeding period in Hapur region); Bhardwaj and Prakash (1980, exploratory behaviour) and Advani and Rana (1984, populations in the desert zone). Its reproductive cycle and population flux in relation to bamboo flowering in the North-eastern Hill Region in India have been studied by Chauhan and Saxena (1982b, c, 1983). Mandal (1982a, d) has studied the breeding of *R. r. arboreus*. Roonwal (1949b) has given details of the ecology, population, food preferences, breeding habits and underground nest structure in *R. r. bullocki* in North - eastern India (Manipur). Arboreal nests have been described by Rajagopalan et al. (1970). Its food preferences have been studied by J.A. Khan (1974, in captivity) and Katoch (1981). Odend'hal (1980) reports its unusual habits of feeding on diseased cattle, and Purohit and Bohra (1973) and Ghose have recorded cannibalism. Subiah (1980) has mentioned the offensive odour of females, while Sud (1976) has studied the effect of light on the reproductive organs, Sekar et al. (1986) the effect of codeine (an alkaloid of opium) on rat intestine, and Spillet (1969b) the rat's growth rate.

Its helminthic parasites have been studied by Singhvi and Johnson (1979-1986), Nama and Khichi (1975, cestodes), and Mathur and Johnson (1982-1985, the effect of helminth infection on physiology). Barnett et al. (1975) have studied its ability to discriminate against poisoned food, Deoras et al. (1972) and Pahawa et al. (1980-1982) the effect of rodenticides, Rai et al. (1982, 1984b,c) its reaction to different baits, Sheikher and Ahmad (1986) the use of water as a carrier for rodenticides, and Parshad (1986) the evaluation of some rodenticides.

7. **Rattus meltada** (Gray)

[Millardia meltada Gray of authors *]*

(The Metad or Soft-furred Field Rat)

India, Nepal and Sri Lanka. Nocturnal. Lives in burrows and cracks, especially in irrigated fields, and in hedges and grasslands. Breeding may be

seasonal or more evenly spread throughout the year. Is a serious pest of agricultural crops.

In Western Rajasthan it prefers grasslands and the edges of cultivated fields (Prakash et al. 1971); Mandal and Ghosh (1980) have recorded its occurrence in West Bengal. Various aspects of its ecology and biology have been studied by Rana (1985, ecological distribution in India), G. Chopra and Sood (1980a, b, 1982, 1983, aspects of behaviour), Rana and Soni (1981, burrowing habits), Dechamma (1979, seasonal weight changes), and Siddiqui and Khan (1982, food preferences). Breeding habits and reproductive biology have been studied by Bindra and Sagar (1968), Guraya and Gupta (1975) and Rana and Prakash (1984). S. Johnson (1978) has described a new nematode parasite from it, while Ojha (1978) has studied its poison shyness.

8. **Rattus norvegicus** (Berkenhout)

(The Brown or Norway Rat)

Introduced from the western palaearctic region but now well established in Indian ports. Widespread in the temperate regions of the Northern Hemisphere, but in tropical countries found mostly in ports where it has been introduced through shipping. Mainly nocturnal. In tropical countries, lives in sewers, cellars, attics, etc. (in its original home in the temporate region, it lives in both farms and cities). Breeds throughout the year.

Though normally confined to ports, it has re-appeared in suburban areas in West Bengal (Mandal 1981a). Jackson (1966) has studied its biology and behaviour, Deoras (1966a) its populations in Bombay) and southwick (1969, in Calcutta), Krishnakumari (1973) has studied its food preferences, Krishnakumari et al. (1979) its food responses to mixed bait, Narayanan et al. (1971) the physiology of activity, and M.V. Rao (1986) the effects of injected thiola on reproductive organs and loss of fertility in males. The chromosomes have been studied by G.P. Sharma et al. (1982, effect of carcinogens on bone marrow chromosomes) and G.P. Sharma and Anand (1984, chromosome aberrations induced by some halogenated hydrocarbons). Some work on aspects of control has been done by Price-Evans and Sheppard (1966) and by Redfern and Gill (1978, with an anticoagulant).

9. **Mus musculus** Linnaeus

(The House Mouse)

Original home the palaearctic region; now cosmopolitan due to introduction. Nocturnal. Lives in burrows and crevices. Commensal with man in houses; also found in the field. Is destructive to sacks, textiles, paper, cooked foodstuff, etc. Breeds throughout the year. Not much is known about it in tropical countries.

Little work has been done in India. Roonwal (1949b) records it from Manipur in North-eastern India. For general summaries of its biology, see Southern (1954), Barnett and Prakash (1975) and Berry (1981). Some aspects of its physiology have been studied by Unnithan and Tandon (1982, effects of oestrogens on gonadotrophs, etc.), O. Prasad and Rastogi (1983, haematological abnormalities induced by prefeeding a common food colour, mentanil yellow), N.K. Gupta (1986, cancerous mice), N. Srivastava and Prasad (1986, effect of antioxidant prefeeding on chromosomes in males), Dominic (1963-1976, effect of pheromones on fertility), and Rajendren and Dominic (1984, effect of contact stimuli in male-induced implantation block). Genetical aspects have been studied by P.S. Chauhan et al. (1975, 1984 and Chaubey et al. (1978). The effects of radiated water and food and other radiation effects have been examined by V.C. Shah (1976), Sharan and Srivastava (1980, 1984) Kapoor and Srivastava (1980), P.N. Srivastava et al. (1982) and Ayene and Srivastava (1985). For additives in baits, 4-5 per cent concentration of groundnut oil is preferred over other vegetable oils (Pasahan and Subhlok 1981); and Sheikher and Ahmad (1986) have studied the use of water as a carrier for rodenticides

10. **Mus booduga** (Gray)

(The Little Indian Field Mouse)

India and Bhutan. Nocturnal. Makes small, shallow burrows in fields. Breeds the year round, sometimes seasonally. Does some damage to cultivated fields.

Little recent work has been done. Mandal (1982c) found it at high altitudes, and Mandal and Biswas (1982) record it from Calcutta. Its biology and ecology have been studied by Chandrahas (1974) and Mohana Rao (1974b). The suppression of oestrus has been recorded by Dominic and Pandey (1979).

11. **Nesokia indica** (Gray)

(The Short-tailed Mole Rat or Bandicoot Rat)

Widely distributed in the palaearctic region and north Africa; Turkestan; Sub-Himalayan India (Kumaon, U.P.), Pakistan, Afghanistan, West Aisa and Egypt. Nocturnal. Mostly found in cultivated fields; often burrows. Breeds throughout the year. Damages crops in fields.

Little work has been done on this species. In Western Rajasthan it occurs in the canal irrigated areas of Sri Ganganagar District; its presence is recognised by the occurrence of pyramidal accumulations of earth at the burrow opening which it closes during the day (Prakash, Gupta et al. 1971). The sex chromosomes have been studied by Jhanwar et al. (1971), and S.R.V. Rao et al. (1983, heterochromatin variation). The physiology of reproduction has been discussed by Garyali and Saxena (1975), movements in rice fields by Fulk et al. (1981), and burrow patterns by Ramesh (1977, 1986). Work on control has been done by Peswani et al. (1975) and Ramesh and Katiyar (1985a, b, control in fields).

12. **Bandicota bengalensis** (Gray)

(The Lesser Indian Mole Rat or Bandicoot Rat)

All-India (except the extreme western desert), Nepal, Bangladesh, Sri Lanka and South-east Asia (Burma, Thailand, Vietnam, Sumatra and Java). Nocturnal. Lives in burrows in agricultural fields and towns. Breeds throughout the year. Does considerable damage to crops and grain godowns. A well studied species.

Agarwal and Chakraborty (1976) have revised its taxonomy. Its occurrence in Rajasthan has been recorded by Rana (1980, Western Rajasthan) and by Prakash and Mathur (1979, Bikaner city). Roonwal (1949a) and Subiah and Singh (1984) record its occurrence in Manipur in north-eastern India. Both melanism (Mandal 1986) and albinism (Rai and Srihari 1982) occurs. Various aspects of its anatomy have been touched upon by A.S. Srivastava and Nigam (1971). Blood grouping has been studied by A.S. Srivastava, Nigam and Nigam (1971), haematological change due to the use of rodenticides by Srihari and Shakunthala (1979) and variation in heterochromatin in sex chromosomes by T. Sharma et al. (1973).

Aspects of its biology have been studied by various authors: Sagar and Bindra (1971, burrowing pattern), S. Chakraborty (1975a, habits in the

field, W. Bangal), C.M. George et al. (1981, Kerala), Parrack (1966, 1969) and Parrack and Thomas (1970, biology and behaviour), Raman and Sood (1980b, exploratory behaviour), Sridhara et al. (1978-1979), A.S. Srivastava and Nigam (1971, Uttar Pradesh), Deoras and Pradhan (1975, in Bombay), Frantz (1975), Fernando et al. 1967, Sri Lanka), Nigam (1981-1983, breeding behaviour), Srihari and Rai (1984, annual reproductive cycle), and Srivastava and Nigam (1975a, b, soil moisture and soil types in relation to breeding and development).

Food habits have been studied by Roonwal (1949a, Manipur, plant-stem and fruit), Sridhara (1978, aspects of nutrition), Srihari and Sridhara (1979, food hoarding habits), A.S. Srivastava and Bhaduria (1982, also hoarding behaviour) and Durairaj and Rao (1975, feeding behaviour with oils). Size - and sex-dependant social interactions have been studied by S. Sridhara (1986).

Ecological studies have been made by Spillet (1968, 1969a, populations, 1969b, growth rate), Fulk et al. (1979, 1981, movements in rice fields, using telemitry), and Gill (1978, 1981, ecology and control). Ectoparasitic mites have been reported by Roonwal (1949a) in Manipur.

Cowan et al. (1977) have tested the efficacy of the rodenticide RH-787, while Rai et al. (1983) have used other poisons for control. Batra (1966) has reported on control operations in intensive agriculture areas. A.S. Srivastava and Nigam (1975) have experimented with chaemosterilants. Losses caused to food crops have been estimated by Parrack (1969) and Roy (1974). Control with record generation, single-dose anticuagulant rodenticides has been evaluated by parshad (1986).

13. **Bandicota indica** (Bechstein)

(The Larger Bandicoot Rat)

India and Bangladesh to South-east Asia (Burma, Thailand, Indo-China, Sumatra, Java, South China, Hong Kong and Taiwan). Nocturnal. Lives near human habitations. A powerful burrower and may burrow under floors of houses, even through masonry; burrows organised in colonies. Breeds seasonally. Damages crops and foodstuff stored in houses.

Its biology has been studied by Spillet (1968, 1969b, growth rate), Arjunwadkar and Gadgil (1974, burrowing habits), R. Chakraborty and Chakraborty (1982, food habits, West Bengal) R. Singh and Singh (1985, behaviour towards young ones), and Sridhara and Srihari (1978b).

(B) Other Species

Rodents other than those of economic importance have received little attention. Most of them live in dense and remote forests. But they often present features of great biological and ecological interest which is one reason why they should receive greater attention. Recent information about these species is given below briefly.

Family SCIURIDAE

1. Petaurista magnificus (Hodgson)

(Hodgson's Flying Squirrel)

R.K. Ghose and Saha (1981) have discussed its taxonomic status and describe a new subspecies.

2. Petaurista petaurista (Pallas)

(The Common Gaint Flying Squirrel)

Jamdar (1985) has described its reflected eye-glow.

3. Hylopetes alboniger (Hodgson)

(The Parti-coloured Flying Squirrel)

Its occurrence in Manipur has been reported by Roonwal (1949b).

4. Eupetaurus cinereus Thomas

(The Wooly Flying Squirrel)

Its occurrence in Sikkim has been reported by Agarwal and Chakraborty (1970), while Chakraborty and Agarwal (1978) have described its melanistic forms.

5. Callosciurus erythraeus (Pallas)

(Pallas's Squirrel)

(i) **C.e. erythrogaster** (Blyth) (the Manipur Squirrel). Reported from Lower Assam and Manipur; it feeds on figs and other plants (Roonwal 1949b).

(ii) **C.e. punctatisimus** (Gray) *[Macroxus punctatissimus* Gray of authors*]*. Agarwal and Bhattacharyya (1979) have shown that Gray's *Macroxus punctatissimus* is realy a subspecies of *Callosciurus erythraeus* (Pallas).

6. **Callosciurus pygerythrus** (Geoffroy)

(The Irrawady Squirrel)

S. Ghosh (1980) has reported its carnivorous habits.

7. **Dremomys lokriah** (Hodgson)

(The Orange-bellied Himalayan Squirrel)

D.l. macmillani (Thomas and Wroughton) (Macmillan's Squirrel). It occurs in Manipur where it is common in evergreen jungle and oak scrub; its food consists entirely of vegetable matter (seeds of vine, etc.); the body is infested with mites (Roonwal 1949b).

8. **Funambulus tristriatus** (Waterhouse)

(The Jungle Striped Squirrel)

S.R.V. Rao et al. (1973) have studied its chromosomes, while Bhat and Mathew(1984, 1985) have described its habits in the Western Ghats.

9. **Ratufa indica** (Erxleben)

(The Large Indian Squirrel)

In *Ratufa indica indica,* Borges (1986) records a possible play-behavioral interaction between it and the common langur, *Presbytis entellus,* on a tree.

Family HYSTRICIDAE

10. **Hystrix hodgsoni** (Gray)

(The Crestless Himalayan Porcupine)

It has been recorded from Manipur where it feeds on vegetable matter, e.g., leaves, bits of stem, etc. (Roonwal 1949b).

Family MURIDAE

11. **Pitymys leucurus** Blyth

(Blyth's Vole)

This vole occurs in Tibet, Chinese Turkestan, and along the Himalayas from Ladak and Kashmir to the Mt. Everest area. Its taxonomy has been disscused by Roonwal (1953).

12. **Pitymys sikkimensis** (Hodgson)

(The Sikkim Vole)

It occurs in Sikkim and Bhutan. Intraspecific variation in the external body parts and skull has been studied by Ghose and Guha-Roy (1972).

13. **Gerbillus gleadowi** Murray

(The Little Indian Hairy-footed Gerbil)

Its salt tolerance in deserts has been studied by P.K. Ghosh and Gaur (1966), and its geographical distribution by P.D. Gupta and Agarwal (1966). In the Indian Desert it inhabits a variety of habitats, e.g., sandy, ruderal and gravely, but prefers the sandy areas at the foot of sand dunes (Prakash et al. 1971, and Prakash 1975). C. Singh and Singh (1980a, b) have discussed its epidemiology and control in the Indian Desert; Soni and Prakash (1981) its control with bromodinfacoum; and Rana and Jain (1981) have described its ventral marking gland.

14. **Gerbillus nanus** Blanford

(The Baluchistan Gerbil)

(Syn. *Gerbillus dasyurus* Wagner, vide Petter, 1961, *Mammalia,* **25** Special No.)*

G. nanus indus Thomas. Its biology and distribution in the Indian Desert have been discussed by Prakash and Jain 1971, Prakash et al. 1971, and Prakash 1975 l). Idris (1981) has studied its mid-ventral gland.

15. **Vandeleuria oleracea** Bennett

(The Indian Long-tailed Tree Mouse or Plam Mouse)

Its occurrence in desertic Western Rajasthan has been reported by Rana (1980) and Advani and Mathur (1982a), the latter in rural residential habitats. Geographical variation has been studied by Agarwal and Chakraborty (1980). Rajagopalan et al. (1970) have described its arboreal nest, and Khajuria (1970) the young ones.

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* Not seen in original. Information kindly given by Dr. I. Prakash.

16. **Rattus blenfordi** (Thomas)

(Blanford's Rat)

Its arboreal nest in South India has been described by Rajagopalan et al. (1970). Lice ectoparasites have been reported by Mishra and Dhanda (1972). S.R.V. Rao and Lakhotia (1972) have studied its chromosomes.

17. **Rattus cutchicus** (Wroughton)

(The Cutch Rock-rat)

In the Indian Desert it exclusively prefers rocky habitats, living in crevices; it seems to live singly and has a small range of movements (Prakash et al. 1971, and Prakash, Rana and Jain 1973). Mishra and Kaul (1973) have recorded from it a body - louse (Anoplura).

18. **Rattus gleadowi** (Murray)

[Millardia gleadowi (Murray) of authors *]*

(The Sand-Coloured Rat)

In the Indian Desert it prefers the sandy habitat (Prakash, Gupta et al. 1971). Its burrowing pattern has been studied by Advani and Jain (1982). Chromosomes in male have been examined by Satyaprakash and Aswathanarayana (1971).

19. **Rattus manipulus** (Thomas)

[Berylmus manipulus (Thomas) of authors*]*

(The Manipur Rat)

Its ecology and food habits have been studied in Manipur by Roonwal (1949b). It is a sleek, smooth-furred rat with small eyes adapted to a burrowing habit, and is common in evergreen rain jungle and oak scrub. It feeds on both vegetable (leaves, etc.) and animal matter (insects and *earthworms,* this last being specially noteworthy, the rat's stomach is often full of small, cylindrical pieces of earthworms).

20. **Rattus mentosus** Thomas

[Rattus niviventer mentosus Th. of authors*]*

(The Chin Hills Rat)

Its ecology in Manipur has been studied by Roonwal (1949b). It prefers evergreen rain jungle and feeds mostly on vegetable matter and some insects.

21. **Hadromys humei** (Thomas)

(The Manipur Bush Mouse or Hume's Rat)

In Manipur it is fairly common in oak parkland. Its food consists of grass leaves, and it breeds in September (Roonwal 1949b).

22. **Mus cervicolor** Hodgson

(The Fawn-coloured Mouse)

Its occurrence in the Andaman and Nicobar group of islands has been reported by Mandal and Ghosh (1984).

(i) **Mus cervicolor imphalensis** (Roonwal) *[Leggada nagarum* imphalensis* Roonwal*]*. In Manipur it is common in riverine scrub and meadow, and feeds on vegetable matter (fruits and leaves) and insects (Roonwal 1949b).

(ii) **Mus cervicolor phillipsi** Wroughton. In the Indian Desert it occurs in a variety of habitats but prefers rocky areas (Prakash et al. 1971).

23. **Mus platythrix** Bennett

(The Spiny Field Mouse)

A widespread species in India and Burma. In the Indian Desert it occurs in a variety of habitats (Prakash et al. 1971). Mandal (1985b) report its occurrence in West Bengal. Various aspects of its biology have been studied in recent years: breeding by Chandrahas (1974), migratory behaviour by G.S. Mann (1977b), feeding behaviour by Srihari and Sridhara (1978b) and reproductive biology by Mohan Rao (1981). Chromosomes have been studied by Pathak (1970).

24. **Golunda ellioti** Gray

(The Indian Bush-rat)

In the Indian Desert it prefers the thorny fences of cultivated fields; it is diurnal, being most active in the mornings and evenings (Prakash et al. 1971). Its geographical variation has been studied by Agarwal and Chakraborty (1982), and its control, by means of poison baits, by Soni (1978, 1981).

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* Honacki et al. (1982) regard *L. nagarum* as a Junior synonym of *Mus cookii* Ryley.

XI- FUTURE WORK

For fundamental biological problems rodents provide excellent material. Speaking generally, only the few species of economic importance in India have been studied in any detail. The remainder, which form the bulk of the fauna of the Indian Region, have been hardly touched upon and information on them is at best fragmentary. Ther reasons for this neglect are not to seek. Many rodents live in deep, dense forests and require special efforts for collection and study, and similar limitations apply to the few species which inhabit high altitudes in the Himalayas.

It should be emphasised that each species must be studied carefully in its own right, for it has its own characteristic seasonal life-history, habitat preferences, food habits, reproductive cycle, reproductive potential, behaviour pattern, population dynamics, and reactions to the chemicals used for control. A little studied aspect is the effect of control operations on future populations, taking into account the potential of the species. All these aspects have a close bearing on methods of control.

The taxonomy of the fauna of the Indian Region has been put on a sound foundation by the work of Ellerman (1961, *Fauna of India*), but the faunas of certain remote and poorly accessible regions such as dense forests of North-Eastern India and the Eastern and Western Ghat regions, etc., have not been adequately studied. Among other inadequacies in taxonomical work are, as discussed above in the Section of Taxonomy, the lack of the use of modern collecting techniques for obtaining a large series of specimens, their proper preservation in the form of skins and skulls for satisfactory identification, and their deposit in easily accessible institutions where long-term curating and maintenance are ensured.

Few rodent fossils are known from the Indian Region and adequate search in the appropriate geological formations should yield interesting results.

Except for the common rat (*Rattus rattus*) and the northern palm or five-striped squirrel (*Funambulus pennanti*), the morphology of no other Indian rodents is not adequately known, and there is considerbale scope for work on the comparative morphology of such species. Similarly, work on the hostology, histochemistry and cytochemistry is fragmentary. The chromosomes of several species, however, have been studied in considerable detail; more chromosomal studies specially in relation to geographical and subspecific variations, will be of much interest.

The ecology, biology, population dynamics and behaviour of several species of economic importance have been studied in fair detail, and this feature specially applies to the Indian Desert region (Western Rajasthan) (I. Prakash and co-workers). The non-economic species, specially the forest-dwelling and the high altitude species, however, are known very inadequately except for a few regions such as Manipur (Roonwal 1949b), and aome portions of Uttar Pradesh (A.S. Srivastava and co-workers, 1968 et seq.), the Punjab (Sagar et al.), Gujarat (G.C. Chaturvedi et al. 1975 et seq.), West Bengal (Seal and others) and Karnataka (Srihari and others). There is also wide scope for behavioral studies both in the field and in the laboratory.

Work on the physiology of the Indian species is both limited and cursory, an exception being the gerbils of the Indian Desert whose salt and water requirements have been studied in considerable detail (P.K. Ghosh and co-workers). Some work has also been done on the reproductive physiology, including aspects of birth control. There is wide scope for work on all aspects of physiology, and rodents provide excellent material for this purpose.

Little work has been done on the genetics of Indian rodents, and this aspect should repay study, especially in connection with the inheritance of resistance to rodenticides.

Both the ecto- and endoparasites of Indian rodents have been studied in considerable detail. Ticks, mites, lice and fleas serve as vectors for disease-causing pathogenic organisms and have received much attention. But there are many parts of the country where regional studies have yet to be carried out. Among the endoparasites, bacteria, rickettsiae and viruses have received a good deal of attention. The helminthic parasites have been well studied, especially for the rodents of the Indian Desert (Johnson, Nama, Parihar, Singhvi and others), but other regions have received scant attention.

As is natural, rodents which harbour diseases such as bubonic plague, kyasanur forest disease, scrub typhus and others, have been studied intensively, especially in relation to the epidemiology of the disease. A constant surveillance is very much to be desired.

Inspite of the considerable amount of work that has been done in recent years on various aspects of rodent control, there is wide scope for improvement in the selection of rodenticides and the application of biological agents for control. Some aspects which stand out from a perusal

of the large amount of published literature on rodent control are as follows: (i) Control operations generally carried out have been of a routine nature and of short-term duration. They have never been pursued long enough to achieve permanent or even semi-permanent control to make a lasting impact. (It may be emphasised here that a complete eradication of rodent pest population is not the aim for the simple reason that it is not a practical possibility.) (ii) The economics of control operations have never been adequately worked out. Unless the cost-benefit ratio is satisfactory over a sufficiently long period of time, control operations have little more than a theoretical value. (iii) Our knowledge of the habits, biology, ecology behaviour and physiology of several species, including those of economic importance, is still limited, and intensive research should be continued to discover, in particular, those aspects that have a close bearing on control. (iv) Special attention should be paid to bait reactions, fumigation techniques, prophylactic measures and storage methods. (v) To make an impact, rodent control agencies should be both more numerous and widespread. It is necessary that the central and state governments and the larger civil bodies, such as the municipal corporations and the larger municipalities, should have at least one unit each, doing full-time work on rodent investigations and control. Regional bodies have their importance since the fontrol problem as regards the species involved and the ecological conditions vary from region to region.

XII. SUMMARY

The rodent fauna (Mammalia: Rodentia) of the Indian Region comprises some 46 genera, 128 species and 260 subspecies and includes such animals as squirrels, porcupines, gerboas, dormice, bamboo-rats, rats, mice, bandicoots, hamsters, voles, and gerbils. They are grouped into six families, viz., Sciuridae, Hystricidae, Dipodidae, Muscardinidae, Rhizomyidae and Muridae. About a dozen species are of great economic importance to agriculture (they cause damage to crops, fruit trees and grain in storage), and some species serve as disease reservoirs and as the primary hosts of vectors of deadly diseases such as bubonic plague, Kyasanur forest disease, scrub typhus, murine typhus, leichmaniesis, etc. Periodically rodents multiply in enormous numbers and the population reaches plague proportions.

Rodents, especially those of economic importance, have been the subject of considerable study in India, but their study has been greatly intensified in the last two decades, especially after the Second World War, and the Bibliography which is appended includes over 1,000 references. This vast literature has been assessed here to take stock of recent advances. The account covers all aspects of Rodentology including such topics as taxonomy, distribution, zoogeography, fossils, anatomy, morphology, histology, cytology, histochemistry, cytochemistry, ecology, biology, reproduction, food, population changes, behaviour, physiology, genetics, parasites (both ectoparasites, e.g., ticks, mites, lice, fleas, and endoparasites, e.g., bacteria, rickettsiae, helminthic worms), rodents and disease and rodent control. A separate section gives the species accoutn in some detail especially for those species which are of economic importance. Finally, suggestions for future work in various fields are given in order to fill the lacunae in our knowledge which have come to light as a result of this review.

XIII. ACKNOWLEDGEMENTS

I acknowledge with thanks the valuable assistance received from the following persons: To Dr. Ishwar Prakash (the Central Arid Zone Research Institute, Jodhpur), Dr. Ram Sewak, Mrs. Padma Bohra and Mrs. Neena Tak (the Zoological Survey of India, Jodhpur) and Dr. P.J. Deoras (Bombay) in the preparation of the Bibliography. Dr. To N.S. Rathore (Z.S.I., Jodhpur) for the drawing in Figure 1. To Dr. Ishwar Prakash and Dr. R.C. Sharma (Z.S.I., Jodhpur) for kindly going through the manuscript and suggesting useful changes. Dr. N.S. Rathore kindly read the proofs.

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