Model Training Course

Management of Vertebrate Pests in Drylands for Enhancing Farmers Income

October 15-22, 2019

COMPENDIUM

SPONSORED BY

Directorate of Extension
Department of Agriculture, Cooperation & Farmers Welfare
Ministry of Agriculture & Farmers Welfare (GOI), New Delhi

ORGANIZED BY

All India Network Project on Vertebrate Pest Management
ICAR-Central Arid Zone Research Institute, Jodhpur-342001

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On

Management of Vertebrate Pests in Drylands for Enhancing Farmers Income

October 15-22, 2019

Dr. R.S. Tripathi
Dr. Vipin Chaudhary

All India Network Project on Vertebrate Pest Management
ICAR-Central Arid Zone Research Institute
Jodhpur-342001

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भाकृअनुप–केन्द्रीय शुष्क क्षेत्र अनुसंधान संस्थान
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डॉ. ओम प्रकाश यादव
निदेशक
Dr. O.P. Yadav
Director

Foreword

A large number of vertebrate species, like rodents have been a serious problem in agriculture and storage. Likewise, many depredatory birds cause extensive damage to standing crops. In recent years, serious human wildlife conflict is being noticed in agricultural sectors also where these animals especially blue bulls and wild boars are raiding the standing crops inflicting heavy losses. The ICAR-Central Arid Zone Research Institute, Jodhpur is a premiere Institute in initiating Research & Developmental activities on these problem species, especially the rodents which are one of the most destructive vertebrate pests. The Institute, being the headquarters of All India Network Project on Vertebrate Pest Management, is also coordinating and monitoring the national research in this field. The Project has evolved several technologies for management of these pests. The extension functionaries need to be trained in this important field of plant protection so that the technologies are further effectively transferred to the farmers and other stakeholders. Considering the urgent need of capacity building of extension officials and field functionaries, and the expertise available with the Institute, Department of Agriculture, Cooperation and Farmers Welfare, Ministry of Agriculture and Farmers Welfare (Govt of India) has awarded a Model Training Course on 'Management of Vertebrate Pests in Drylands for Enhancing Farmers Income' from October 15-22, 2019.

I am happy that a Compendium of lectures from various experts is being brought out by the organizers on this occasion. The Compendium covers various issues analyzing the problem of each category of vertebrate pests viz., rodents, birds, wild boars, blue bull, bats etc and developing the techniques of their management in agriculture. Since many legal issues are also involved in dealing with such animals, expert lectures on 'Wild Life Act' and 'Human Wild life Conflict' would be of great help in creating overall awareness among the public. I am sure this compilation would be highly useful to extension officials, field functionaries and scientists in understanding the problem of vertebrate pests and their management.

I congratulate Course Director, Dr R.S. Tripathi, and Co-Director, Dr Vipin Chaudhary for organizing the Model Training Course on such an important topic and bringing out this Compendium. The expert resource persons drawn from various parts of the Country too deserve special thanks for their contribution in this compilation.

Date: October 07, 2019 **(O.P. Yadav)** 7.10.19

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PREFACE

Adoption of improved crop production and protection technologies, like high yielding varieties, fertilizers and pesticides have been helpful in making India a self-sufficient nation in food production. With the advancement of improvement in technologies, populations of many opportunistic animals, like invertebrates (insects, mites etc.) and vertebrates (rodents, birds and some higher vertebrates) has increased manifold, challenging the food production in a big way. Among these, the damage caused by vertebrate pests like rodents alone inflict almost 15% loss to our food basket. Likewise many bird species though regarded as beneficial fauna, however a few of them are depredatory in nature and cause significant damage to arable and perennial crops. In recent years Human-Wild life conflict is also been encountered in agriculture as many higher vertebrates, like blue bull, wild boars, monkeys, elephants etc. take a heavy toll from our crop fields. There is an urgent need to manage these vertebrate pets effectively for enhanced crop production. AINP on Vertebrate Pest Management (VPM), an ICAR sponsored national programme has evolved many effective technologies that needs to be transferred to the end users.

There is an acute shortage of trained manpower in this highly specialized field, and to bridge this gap, AINP-VPM has been undertaking capacity building activities at various level. The Model Training Course (MTC) on 'Management of Vertebrate Pests in Drylands for Enhancing Farmers Income' sponsored by Directorate of Extension, Ministry of Agriculture and Farmers Welfare (Govt of India), is an important step in this direction. This MTC is being organized by ICAR-Central Arid Zone Research Institute, Jodhpur from October, 15-22, 2019. The present publication is a compilation of lectures covering various aspects of bio-ecology and management of such pests from experts. Attempts have also been made to include a lecture on Wildlife Protection Act, 1972 so that the participants are aware of legal issue pertaining to management of vertebrate pests. Besides these, topics on management of Bats, Snail & Slugs, Mite and insect pests and nematodes has also been included in the Compendium.

We express our sincere thanks to Directorate of Extension, Department of Agriculture and Cooperation, Ministry of Agriculture and Farmers Welfare (GOI) for sponsoring this eight-day programme. Thanks are also due to all the expert resource persons who have contributed in this Compendium and would be delivering their lectures. We also record our grateful thanks to Dr O.P. Yadav, Director, Central Arid Zone Research Institute, Jodhpur for his encouragement and sincere guidance in bringing out this publication. Last but the not the least my thanks are also due to my colleagues, Mr Surjeet Singh, Mr R.C. Meena, Dr K.M. Gawaria, and Mrs Rajni Mathur for their support in compilation of this compendium.

We are sure that this Compendium will be of great help to all the participants of this Model Training Course.

R.S. Tripathi
Vipin Chaudhary

Model Training Course on 'Management of Vertebrate Pests in Drylands for Enhancing Farmers Income' (October 15-22, 2019)

Program Schedule

Day 1. (15.10.2019)

Time	Title of Lecture/Practical	Resource persons
9.00- 10.00 AM	Registration	Mr Surjeet Singh & Mrs Rajni Mathur
10.00- 11.30	Inaugural Session	
11.30- 12.00	Inaugural Tea	
12.00- 01.30	Vertebrates: An overview	Dr Vipin Chaudhary
01.30- 02.30	LUNCH BREAK	
02.30- 04.00	Human Wild Life Conflict in agricultural Landscape: Issues and Strategies	Dr V. Vasudeva Rao
04.00 - 05.30	Rodents: A Threat to Food and Health Security	Dr R. S. Tripathi

Day 2. (16.10.2019)

Time	Title of Lecture/Practical	Resource persons
09.00- 10.30	Bio ecology of rodent pests	Dr Vipin Chaudhary
10.30- 12.00	Depredatory birds and their damage patterns in agricultural and horticultural crops	Dr V. Vasudeva Rao
12.00- 01.30	Rodents of Economic Importance in agriculture and Storage	Dr R. S. Tripathi
01.30- 02.30	LUNCH BREAK	
02.30-04.00	Integrated bird management techniques in reducing damage in agricultural and horticultural crops	Dr V. Vasudeva Rao
04.00- 05.30	Collection, handling, maintenance and identification of rodents. Identification of major rodent pest species (Practical)	Dr Vipin Chaudhary, Mr R.C. Meena, Mr Surjeet Singh

Day 3. (17.10.2019)

Time	Title of Lecture/Practical	Resource persons
09.00- 10.30	Rodent Management in Field crops	Dr R. S. Tripathi
10.30- 12.00	Utilization of solar energy for managing higher vertebrates	Dr P. Santra
12.00-01.30	Conservation and Management of Monkey population in Rajasthan	Dr Hemant Joshi
01.30- 02.30	LUNCH BREAK	
02.30-04.00	Eco- friendly management of higher vertebrates with special reference to wild boars	Dr V. Vasudeva Rao
04.00-06.00	Bio-acoustic: a promising tool for management of higher vertebrates and Mapping of vertebrate pests in agricultural landscape using Geo Spatial tools (Practical)	Dr V. Vasudeva Rao

Day 4. (18.10.2019)

Time	Title of Lecture/Practical	Resource persons
09.00-10.30	Chiropteran (bats) diversity and its significance to farmers	Dr. Ashok Purohit
10.30-12.00	Management of Blue bull with special reference to reproductive manipulation techniques	Dr Sharvan Singh Rathore
12.00-01.30	Non-Chemical methods of Rodent Management	Dr N. Srinivasa Rao
01.30-02.30	LUNCH BREAK	
02.30- 03.30	Rodenticides in Rodent Management	Dr R. S. Tripathi
03.30-05.00	Role of rodent behavior in Rodent management	Dr N. Srinivasa Rao
05.00-06.00	Rodenticide Baiting (Practical)	Dr Vipin Chaudhary, Mr R.C. Meena, Mr Surjeet Singh

Day 5. (19.10.2019)

Time	Title of Lecture/Practical	Resource persons
09.00- 10.30	Poison aversion and Bait shyness in rodents	Dr Mohd Idrish
10.30-12.00	Transmission potential of parasitic diseases by rodents to animals and humans	Dr. L.D. Singla
12.00-01.30	Rodent management in poultry farms	Dr Neena Singla
01.30-02.30	LUNCH BRAEK	
02.30- 04.00	Survey techniques and monitoring of rodent population	Vipin Chaudhary
04.00-05.30	Rodent management in commensal sites and storage. Visit to Warehouse/ godowns/ grain Mandis for Practical on rodent problem diagnosis and rodent management in storage (Theory + Practical)	Dr Vipin Chaudhary, Mr R.C. Meena, Dr K.L. Gawaria and Mr Surjeet Singh

Day 6. (20.10.2019)

08.30- 05.00	Field practical exercises on: Assessment crop damage and rodent population, identification of burrows, placement of traps, working out tarp index, live burrow counts, Bait preparation and application, Burrow fumigation and assessment of control success etc at Farmers' fields	Dr R S Tripathi, Dr Vipin Chaudhary, Mr R C Meena, Dr K L Gawaria and Mr Surjeet Singh

Day 7. (21.10.2019)

Time	Title of Lecture/Practical	Resource persons
09.00-10.30	Rodent Management Campaigns: Andhra Pradesh Model	Dr N. Srinivasa Rao
10.30-12.00	Wild life Protection Act of India (1972)	Dr Summit Dookia
12.00-01.30	Non- insect pests and their management in drylands	Dr M.M. Kumawat
01.30-02.30	LUNCH BREAK	
02.30-04.00	Bio-ecology of Blue Bull and its management in	Dr Sumit Dookia

	agriculture	
04.00-05.30	Exposure on experimental fields in CAZRI, including Solar Energy Yard, Horticulture, Protected Cultivation Dairy etc	Dr Vipin Chaudhary, Mr R.C. Meena, Dr K.L. Gawaria and Mr Surjeet Singh

Day 8. (22.10.2019)

Time	**Title of Lecture/Practical**	**Resource persons**
09.00- 10.30	Nematode problems and their management in horticultural crops of arid region	Dr R. K. Kaul
10.30- 12.00	Integrated pest management for low rainfall areas	Dr Nisha Patel
12.00-01.30	Feedback, interaction with trainee participants and Post training evaluation	Participants and Course Director/ Co-Director
01.30- 02.30	LUNCH BRAEK	
2.30- 04.00	Valedictory Session	

VERTEBRATES: AN OVER VIEW

Vipin Chaudhary

All India Network Project on Vertebrate Pest management
ICAR-Central Arid Zone Research Institute, Jodhpur-342 003

1. INTRODUCTION

The vertebrates belong to phylum: Chordata under animal kingdom. Phylum Chordata is further classified under three sub-phyla, viz., Urochordata, Cephalochordata (Branchiostoma) and Vertebrata. The urochordates are marine animals characterized with presence of notochord in the tail region in larval stages. It is further divided in three classes. The cephalochordates, also called as Branchiostoma consist of marine fauna with marine animals showing presence of notochord, dorsal hollow nerve chord, endostyle, pharynx and post anal tail. The third sub phylum, the biggest among chordates comprise of wide variety of animals from aquatic (marine and freshwater), amphibians and terrestrial life and are grouped under seven classes. The vertebrates are generally characterized by presence of vertebral column. A broad classification of phylum chordate is as follows:

2. CLASSIFICATION

Kingdom: Animalia
Phylum: Chordata
1. Subphylum Urochordata
Class Ascidiacea (Ciona)
Class Thaliacea (Doliolium)
Class Larvacea (Oikopleura)
2. Subphylum Cephalochordata (Branchiostoma)
3. Subphylum Vertebrata
Class Agnatha (lampreys and hagfish)
Class Elasmobranchiomorphi (Chondrichthyes) (cartilaginous fishes)
Class Teleostomi (Osteichthyes) (bony fishes)
Class Amphibia (salamanders, frogs and toads)
Class Reptilia (snakes, lizards, turtles and crocodiles)
Class Aves (birds)
Class Mammalia (mammals)

Vertebrate are also called Craniata. They have backbones, from which they derive their name. The vertebrates are also characterized by a muscular system consisting primarily of bilaterally paired masses and a central nervous system partly enclosed within the backbone.

3. GENERAL FEATURES

Although the vertebral column is perhaps the most obvious vertebrate feature, it was not present in the first vertebrates, which probably had only a notochord. The vertebrate has a distinct head, with a differentiated tubular brain and three pairs of sense organs (nasal, optic, and otic). The body is divided into trunk and tail regions. The presence of pharyngeal slits with gills indicates a relatively high metabolic rate. A well-developed notochord enclosed in perichordal connective tissue, with a tubular spinal cord in a connective tissue canal above it, is flanked by a number of segmented muscle masses. A sensory ganglion develops on the dorsal root of the spinal nerve, and segmental autonomic ganglia grow below the notochord. The trunk region is filled with a large, bilateral body cavity (coelom) with contained viscera, and this coelom extends anteriorly into the visceral arches. A digestive system consists of an esophagus extending from the pharynx to the stomach and a gut from the stomach to the anus. A distinct heart, anteroventral to the liver, is enclosed in a pericardial sac. A basic pattern of closed circulatory vessels is largely preserved in most living forms. Unique, bilateral kidneys lie retroperitoneally (dorsal to the main body cavity) and serve blood maintenance and excretory functions. Reproductive organs are formed from tissue adjacent to the kidneys; this original close association is attested by the tubular connections seen in males of living forms. The ducts of the excretory organs open through the body wall into a cloacal chamber, as does the anus of the digestive tract. Reproductive cells are shed through nearby abdominal pores or through special ducts. A muscular tail continues the axial musculature of the trunk.

Approximately 45,000 living species constitute the vertebrates. Species of several classes are found from the high Arctic or Antarctic to the tropics around the Earth; they are missing only from interior Antarctica and Greenland and from the North Polar ice pack. In size, vertebrates range from minute fishes to elephants and whales (of up to 100 tons), the largest animals ever to have existed. Vertebrates are adapted to life underground, on the surface, and in the air. They feed upon plants, invertebrate animals, and one another. Vertebrate faunas are important to humans for food and recreation.

4. NATURAL HISTORY

In order to give a broad and comparative view of their life histories, the vertebrates are subdivided here into major groups based on morphology: the cyclostomes (Jawless fishes), the chondrichthyes (Cartilaginous fishes), the teleostomes (Bony fishes), and the tetrapods. A brief description of these groups is given as under:

1. Cyclostomes: The cyclostomes include two classes of living, jawless fishes (agnathous)—Petromyzontiformes (lamprey eels) and Myxiniformes (hag fishes). The hagfishes are totally marine, often living in deep waters associated with muddy bottoms. The lampreys may be marine as adults but spawn in fresh waters, where the larvae spend some time before metamorphosing to the adult. Some lampreys live entirely in fresh water and may change only slightly in habit as a result of metamorphosis. Without lateral fins, lampreys swim by undulations of the body and can control direction only for short distances.

The living agnaths are predatory, the lampreys being well known for attacking salmonoid fishes. The lamprey attaches to its prey using its round, suctorial mouth, and it rasps a hole through the outer tissues using a tongue armed with keratinized teeth. It suctions off bits of tissue, blood, and body fluids. The hagfishes feed somewhat similarly, but on a variety of prey—invertebrates (worms and soft-bodied forms) and dead fishes.

The lampreys produce small eggs, which develop directly into larvae that burrow into the muddy bottom of the stream. With its mouth at the surface of the mud, the larva filter feeds until large enough to metamorphose and swim off as a small adult. In contrast, the hagfishes produce relatively large encapsulated, yolky eggs up to two centimetres in length. When laid, these eggs attach to any available object by terminal hooks. The encased egg develops more or less directly into a miniature adult.

2. Chondrichthyes: The group includes sharks, rays, and chimaerids which are usually marine, but some sharks have entered fresh waters (the Amazon) or even live there permanently (Lake Nicaragua). In size, sharks range from the whale shark, nearly 10 meters in length, to rather small species of three centimeters in length. They usually weigh 25 to 200 Kgs (55 to 440 pounds). Sharks are predatory animals. Some large shark species (basking and whale sharks) filter feed on small crustaceans. Herbivorous sharks are unknown. Sharks swim by undulations of the tail, but rays "fly" through the water by undulations of the pectoral fins. Most species occur in near-shore waters, but some range widely throughout the oceans. A few are found in deep water.

A few sharks produce live young (viviparous) after internal fertilization. The posterior angle of the male's pelvic fins are modified into a clasper, which acts as an intromittent organ in copulating with the female. Most sharks lay large yolky, encapsulated eggs with hooks for attachment. The young develop directly and begin life as miniature adults. The young that develop in the mother's uterus obtain nutrients from the large yolk sac until they are born alive. In a few cases, the uterine wall secretes nutrients.

The teleostome, or osteichthyian, fishes (those having an internal bony skeleton) can be divided into two groups: the subclasses Actinopterygii (ray-finned fishes) and Sarcopterygii (lobe-finned fishes). The latter group includes the lungfishes, which live in marshes, ponds, or streams, and are frequent air breathers. They lay fairly large eggs, with a limited amount of yolk, that are enclosed in jelly coats like those of an amphibian. The eggs develop into small fishes that feed on live prey. The larvae of the African lungfish have external gills to supplement oxygen intake.

3. Teleostomes: This group comprises of Actinopterygian fishes which are the common bony fishes of modern aquatic environments. They range in size from fishes that are only few milimeters in size to those of two or more meters (6.6 or more feet) in length, weighing 500 Kgs or more. Large species (sturgeons) are found in fresh waters (several other large species are found in the Amazon) as well as in marine environments. Their diet may include plants, animals, and carrion. Most species are midwater swimmers, but many spend much time lying on the bottom. Tail, pectoral, and even dorsal fins are used in swimming. Reproduction in this group is by way of large numbers of small eggs, which produce small larvae or develop directly to the adult.

4. Tetrapods: The tetrapods live primarily on land and are rather similar in habit. Members include the amphibians, reptiles, birds, and mammals.

i) Amphibia: Amphibians are widespread in the warmer parts of the continents, being absent only in the far north and in the Antarctic. Three orders are recognized: Candata (the salamanders), the frogs and toads (Anura, or Salientia), and the Apoda or Gymnophiona (caecilians). Modification takes many forms, from the moist glandular skin (some scale remnants persist in apodans) to the loss of many of the bones of the skull. Like their ancestors, amphibians are cold-blooded and tend to be aquatic or limited to moist surroundings. Salamanders are seemingly the least modified in body form. They do not actively pursue prey and at best are only marginal swimmers. In swimming or crawling, the salamander's body and tail undulate. Frogs and toads hop using hind-limb propulsion and the forelimbs as body props. This dominance of the hind limb in locomotion is best seen in swimming when the forelimbs are drawn back against the body. In contrast to the salamanders and frogs, the burrowing, wormlike apodans are without limbs.

Amphibians usually trap food using a tongue that can be shot out of the mouth, or they use the mouth itself to grasp and ingest food. There is great variation in foods; only the larvae of frogs and toads appear to be plant feeders, a specialization that is reflected in the highly modified jaws and guts of the tadpoles.

Amphibians have retained a simple egg cell with a gelatinous cover. The eggs are laid in ponds, streams, or even in damp places high in trees, usually in great numbers. Fertilized eggs develop into free-swimming larvae, which then metamorphose to adults, but in highly specialized forms.

ii) Reptilia: The class Reptilia retains many of the structural characteristics of the ancestral amphibian. While most reptiles are carnivorous, feeding on other organisms, a few are herbivorous (*e.g.,* tortoises). As cold-blooded animals, reptiles tend to be limited to temperate and tropical areas, but, where found, they are relatively common, although not as large or conspicuous as birds or mammals. Most reptiles are terrestrial, but a few are aquatic. As basic tetrapods, reptiles move about by creeping or swimming in a fashion similar to amphibians. Some reptiles, however, can lift the body from the ground and run rapidly either in a quadrupedal or bipedal fashion. Reptiles lay relatively large, shelled eggs. In a few instances, the eggs and young are cared for by the female; in others, the young are born alive (ovovivipary).

iii) Aves: The aves are numerically the most successful class of Tetrapoda. There are over 10,000 species of bird's world over classified under 24 orders and 146 families. More than half of the avean fauna are passerines or perching birds. They are warm-blooded vertebrates characterized by feathers, toothless beaked jaws, laying hard shelled eggs, high metabolic rates, four chambered heart and a strong but light skeleton.The size of birds varies from 5 cm (bee humming bird) to 2.75 m (ostrich). Most of the bird fauna are capable of flight, others are sedentary and some are flightless (penguins). Like their relatives the reptiles, birds lay shelled eggs that differ largely in the amount of calcification (hardening) of the shell. The young are usually cared for in a nest until they are capable of flight and self-feeding, but some birds hatch in a well-developed state that allows them to begin feeding immediately or even take flight. The megapods lay their eggs in mounds of rotting vegetation, which supplies the heat for incubation. (Nesting activities similar to those of some birds are seen in the crocodilians). In India about 1300 species of birds are reported, however only 63 species are reported to inflict damage to agricultural crops. The birds like, mynas, parakeets, peafowls, bulbuls etc are regarded as depredatory in agricultural ecosystems.

iv) Mammalia: As the name indicates the mammals possess mammary glands for nursing their young ones. They are warm blooded animals. Besides the presence of mammary glands, other characteristic features of mammals are (i) Possession of true hairs and sweat glands (ii) possession of different types of teeth as per feeding requirements (iii) possession of link between mother and foetus "placenta" and parental care of young ones. The mammals range in size from tiny shrews or small bats weighing only a few grams to the largest known animals, the whales. Baseed on the size, the mammals are broadly grouped under three categories, like (i) small mammals (Head body length is <30 cm); medium sized mammals (Head body between 30-100 cms) and large sized mammals (Head body length is >100 cms). Most mammals are terrestrial, feeding on both animal and vegetable matter, but a few are partially aquatic or entirely so, as in the case of the whales or porpoises. Mammals move about in a great variety of ways: burrowing, bipedal or tetrapedal running, flying, or swimming. Reproduction in mammals is usually viviparous, the young developing in the uterus, where nutritive materials are made available through an allantoic placenta or, in a few cases, a yolk sac. The fertilized egg develops directly into the adult. The monotremes (platypus and echidna) differ from other mammals in that they lay eggs which hatch, and the relatively undeveloped young are carried in a pouch or kept in a nest; the growing young lap up a milk nutrient fluid exuded from the belly of the mother. Globally 4307 sp of mammals have been reported, of which 390 species under 180 genera representing 13 orders have been reported from India. However only a few species are problematic in agriculture. For example, rodents, one of the largest group of mammals represented by 103 species in India, only around a dozen species are considered pests in agriculture and storage. Likewise, in order chiroptera one species i.e., Indian flying fox or the fruit bat (Pteropus giganteus) damages fruit crops. Other bat species like small fruit bats, Cynopterus sphinx and Rousettus leschenaulti are of very minor significance. Some higher vertebrates like, monkeys, wild boars, nilgais, rodents, elephant, gaur etc have also been observed to cause severe damage to standing crops (Table1 &2).

Table 1. Mammalian Diversity in India

Orders	**No of Families**	**No of Genera**	**No of Species**
Insectivora (Shrews, hedghogs and moles)	3	11	28
Chiroptera (Flying foxes, Bats)	6	36	110
Primates (*Monkeys, langoorsgorillas, Humans)	3	6	15
Pholidota (pangolins, ant eaters)	1	1	2
Carnivora (Tigers, Hyaenas, Cats, foxes, Mongoose etc)	7	33	55
Artiodactyla (Even toed animals, Boars, Pigs, Camel, Giraffe, Deer, Hippos, Goats, Sheep, Nilgais, Cattle etc)	5	20	32
Lagomorpha (Hares & Rabbits)	2	3	10
Rodentia (Rats, Mice, Bandicoots, Porcupines, Squirrels etc)	4	43	103
Proboscidia (Elephants)	1	1	1
Sirenia (sea cows mantees)	1	1	1

Perssodactyla (Odd toed like: Rhinos horses, donkeys etc)	2	2	3
Cetacia (Whales, Dolphins)	6	21	29
Scandentia (Tree shrews)	1	2	3
TOTAL	**42**	**180**	**390**

Among all the groups of vertebrates only a few species of aves and mammals which are mainly herbivores are considered as problem (pest) species in agriculture (Table 2).

Table 2: Vertebrates of economic importance in Agriculture in India

Group	**Total Sp.**	**No. of Sp. involved in Crop damage**
Birds	1300	63
Bats	-	1
Rodents	103	10-12
Antelopes	6	3
Deers	9	1
Elephant	1	1
Gaur	1	1
Wild boar	1	1
Black napped hare	1	1
Primates	13	5

HUMAN – WILDLIFE CONFLICT IN AGRICULTURAL LANDSCAPE: ISSUES AND STRATEGIES

V. Vasudev Rao

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INTRODUCTION

Human-Wildlife Conflict (HWC) is defined as any interaction between wildlife and humans which causes harm, whether it is to the humans or wild animals or property (including the destruction of crops). Conflict arises from a range of direct and indirect negative interactions between humans and wildlife. These can culminate in potential harm to all involved, and lead to negative human attitudes, with a decrease in human appreciation of wildlife and potentially severe detrimental effects for conservation (De Boer & Baquete, 1998; Nyhus et al., 2000). Conflict generally arises from economic losses to agriculture, including loss of cattle through predation and destruction of crops. In arid areas it often occurs over access to water and competition for resources.

A wide range of species is responsible for conflict, with the principal culprits being primates, rodents, ungulates (including antelope, wild boar, elephant, tiger, lion and leopards). Livestock also perpetrate significant damage, however, there are often locally accepted measures of restitution (Naughton- Treves, 1998). Conflict situations can arise anywhere, and are frequently concentrated at the fringes of reserves where wildlife enjoys protection and land is often fertile, leading to a wealth of agriculture.

There are other socioeconomic costs associated with human-wildlife conflict which can outweigh the direct costs of agricultural damage and be a major component of the conflict as perceived by local people (WWF, 1997). The extreme example of this is human death, but other examples include restrictions on movement, competition for water sources, the need to guard property (which may lead to loss of sleep), poor employment opportunities and increased psychological stress.

The basic reasons for Human-Wildlife Conflict is the loss of species-specific habitats, habitat degradation and fragmentation, intensive agricultural practices, insufficient prey base and food material, increase in human and livestock population, competitive exclusion of wild herbivores, land use transformation, developmental activities, growing interest in ecotourism and increasing access to nature reserves. The basic requirements of space, shelter and food overlap between humans and wildlife, creating conflicts.

Management of problematic species mainly depends on their status as per the Indian Wildlife Protection Act 1972 (IWPA) and International Union for Conservation Nature (IUCN). The species like tiger, leopard, lion, sloth bear, snow leopard, elephant, black buck, gaur and crocodile are kept under Schedule–I, species like rhesus macaque, bonnet macaque and wild dog are listed under Schedule–II and other problematic species like wild boar, nilgai are covered under schedule–III of IWPA. Whereas, as per IUCN, tiger, snow leopard, elephant and wild dog are listed as endangered; lion, sloth bear, gaur and crocodile are listed as vulnerable; leopard and black buck listed as near threatened and others like wild boar, nilgai, rhesus macaque, bonnet macaque are listed as least concerned species. The status of these species as per IWPA and IUCN is the hurdle while dealing with the species in agro-pastoral ecosystems.

Apart from these, the major constraints in vertebrate pest management are: lack of sustained efforts at local level, strong religious sentiments against killing, high cost of eliminating animals, lack of coordination with district authorities and lengthy procedure for declaration as vermin.

AGRICULTURAL DAMAGES DUE TO WILDLIFE

All the animals and birds listed in India are not problematic in causing HWC. Among the 103 species of rodents listed, only 13 species were found to be involved in agricultural damage at different growth stages of the crop. In case of birds of the1364 species, 63 species were identified as depredatory in nature and causing damage to various agriculture and horticultural crops mostly during vulnerable stages of the crops. Among the six antelopes reported in India, three species like nilgai, black buck and four horned antelope were reported as crop riders. Similarly, of the nine deer species, only spotted deer has been reported involving crop damage in the fringes of forest blocks. Out of 13 species of primates listed, five species are involved in crop damage across different agro-ecological regions. The other species like elephant predominantly causes crop damage, property loss and injuries to humans mostly in forest fringes and also during migration across the corridors. The wild boar is the most problematic species causing significant crop damage across different agro-climatic zones of the country.

Studies conducted by the All India Network Project on Vertebrate Pest Management over a decade showed that the extent of damage caused by different species of rodents was to the tune of 15%, followed by birds 9%. Recent studies revealed that the wild boar damage to different crops varies from 15-40%, nilgai to the extent of 10-30%, elephants, 20-50%, rhesus macaque, 10-30%, black buck, 5-15% and gaur, 5-10%. The intensity of damage depends on population density, cropping pattern, extent of crop area, season and stage of the crop.

Carnivores often cause serious economic and social losses by preying on livestock, causing damage to property and general community insecurity, and in exceptional cases, human injury or death (Madhusudan and Mishra, 2003; Mishra et al., 2003; Distefano, 2005; Ogra and Badola, 2008; Ogra 2008; Lee, 2011). The economic loss due to snow leopards (*Panthera uncia*) and wolves in Spiti region of the Indian Trans-Himalaya has been estimated at Rs. 8000 per family annually, amounting to about half the per capita income of the state (Mishra 1997). Also, a similar study by Maheshwari et al. (2010) showed over 2% livestock loss every year due to snow leopard, Tibetan wolf and Himalayan brown bear (*Ursus arctos isabellinus*) in Kargil, Ladakh. The impact is exacerbated if the loss is of human life. Similarly, during 2007-2011 a total of 888 human deaths were reported across several regions due to wild animals and compensation was reported to the tune of Rs. 5.72 crores. In case of human injuries, a total of 7,381 cases were reported with a compensation of Rs. 3.4 crores. Several crop damage cases were also reported by wild animals and compensation paid to the extent of Rs. 10 crores. The antagonism arising from conflict with carnivores pushes people towards retributive killings that have a substantial impact on the carnivore population undermining the conservation efforts (Woodroffe et al. 2005, Dickman, 2008; Hazzah et al., 2009). Therefore, reducing antagonism caused mortality is an important strategy for conservation of carnivores (Lee, 2011).

GENERAL ISSUES RELATED TO TARGET ANIMALS FOR R&D ACTIVITIES

1. Risk Assessment: Assessment of population of target animals may be planned along with mapping the pestilence in different agro-ecological zones of the country. The assessment includes behaviour, ecology and niche analysis of target pests.

2. Technology options: Short term: Traditional methods, viz., trenching, fencing (bio as well as mechanical); trap crops and non-chemical methods may be advocated. Formation of National Expert Group comprising of experts from ICAR, AINP VPM, IVRI, MoEF, WII and State Forest Departments can be considered for advisory role. Long term: Sterilization, bioacoustics, reproduction control methods, policy planning, repellents, participatory management plans; Integration of control methods; Creation of database on population vis-a-vis damage patterns in agricultural landscape; Training for awareness creation.

3. Policy imperatives: Advise the Ministry of Environment and Forests to rationalize Wildlife Protection Act in need-based manner and under exigency to facilitate farmers to take timely management measures; Translocation of monkey troops following IUCN guidelines from problematic areas to wild forest area to monkey homes managed by Compassionate Unlimited People for Animals (CUPA) and People for Animals (PFA); With respect to nilgai, farmers are often reluctant to kill due to religious taboo. Hence, emphasis on changing the proposed common name as vanaroz may be considered.

4. Management Issues: The damage caused by wild mammals like Nilgai (blue bull), wild boar and monkeys to agriculture has become a matter of serious concern and needs to be managed effectively. Farmers across the nation are suffering badly due to their menace. Since these animals are protected under Wildlife Protection Act, their management through non-lethal approach is the pre requisite to minimize the crop losses as well as man animal conflict.

5. Legal issues: These animals being protected by Indian Wildlife Protection Act 1972 and Biodiversity Act 2004, hunting or using any lethal method is legally barred. However, in extreme situations the State Governments has been empowered to issue the licences/orders for killing the problematic animals following proper procedure. The Act states, 'The Chief Wildlife Warden or the authorized officer may, if he is satisfied that any wild animal specified in Sch. II Sch, III or Sch. IV has become dangerous to human life or to property (including standing crops on any land) or is so disabled or diseased as to be beyond recovery, by order in writing and stating the reasons therefore, permit any person to hunt such animal or cause such animal to be hunted'. Gujarat has appointed Sarpanches of 1545 villages as Honorary Wildlife Warden under Section 4(1)(bb) and empowered Chief Wildlife Warden under Section 5(2) to delegate his powers to Sarpanches under Section 11(1)(B) to allow hunting of Nilgai in their respective areas. Similarly, in the states like Haryana, Uttarakhand and Uttar Pradesh also the Government has empowered DFOs, District Collectors and Block Development officers to issue permit to kill the problematic nilgai in extreme situations.

STRATEGIES

- Large scale demonstration and popularization of different methods through extension.
- People be discouraged to offer food/feed monkeys around temples and tourist places, wherever they are problematic.
- Preparation and circulation of documents on (i) Wildlife Protection Act schedules concerning the target animals for awareness creation (ii) Technologies available to be demonstrated at pilot scale through ICAR/SAU System (KVK).
- Meetings to be arranged by ICAR for focused discussion with senior officials of MoEF on Wild life Protection Act and other issues related to MoEF-higher vertebrate pests. The agenda may also cover issues in context of human-wildlife conflict.

- Organization of high level meetings for showcasing species-based proven technologies.
- Need based basic research topics to be allocated to students by SAUs/ICAR Institutes for Ph.D. programmes.

Management techniques: In many countries killing of problem species, like wild boars are permitted in special cases. In USA wild boars are controlled by hunting, caging and shooting. Poison baits on a large scale is a widely used method in Pakistan for managing the wild boars. In Bhutan on the other hand, trained group of farmers are employed in hunting the wild boars. Italy is a country where wild boar menace is kept under check by using rodenticides. In some countries like England, Poland, Russia and Japan it is very common to control wild boars by poisoned baits, hunting, shooting, catching, electrocution and translocation etc. Despite the above methods being effective none of them are applicable for Indian conditions as wild boars have been listed in Schedule III of Wild life Protection Act. In the light of such situations development of management practices for higher vertebrates in India need to be strategic, logical, and economical and above all must be legally sound in the light of the Act.

Initiatives taken by ICAR: Keeping in view the severity of the problem in agriculture associated wild animal species; ICAR has launched an All India Network Project on Vertebrate Pest Management during XII Plan period. Besides studies on birds and rodents, management of higher vertebrates is an important component of the Network. The Project envisages to undertake detailed studies on ecology and management of three most important wild animal species, viz., Nilgai (Boselaphus tragocamelus); wild boar (Sus scrofa) and monkey (Macaca sp) to minimize the crop losses vis a vis farmer - animal conflict in agricultural landscape.

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RODENTS: A THREAT TO FOOD AND HEALTH SECURITY

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INTRODUCTION

India has significantly marched ahead during last over six decades for food scarcity o food self-sufficiency. During 1950s the total food grain production was merely 52.2 MT, which has now crossed 280 MT now. Major contributing factors for such an impressive increase include high yielding varieties and hybrids, assured irrigation, use of fertlizers and pesticides, credit facilities, minimum support price, improved infrastructure, more efficient use of water and hardworking innovative farmers. That is why now the focus is shifted from food security to nutritional security. Besides one of the major concerns is to meet the food and nutritional requirements of the ever-increasing human population which was only 1.10 billion in 1911 is now over 1.35 billion and is expected to increase to over 1.50 billion by 2040. Government of India and states have launched several programs to meet the challenge. Prime Minister has given a call to double the farmer's income by 2022. Agriculture in India is often fraught with great deal of risks from nature's fury like draughts, floods, incessant and untimely rains, climate change etc.

Analysis of several such factors, opportunities and challenges, it is very clear that besides addressing these issues related to crop production, we must lay greater emphasis on protection strategies also, because besides these abiotic constraints, a significant amount of food is lost due to vagaries of pests and diseases at every stage of crop production, processing and storage. Post green revolution the problem of pests and diseases has become much more complex due to changes in cropping patterns, intensive agriculture, higher use of chemical fertilizers and climate change etc. As per the data of 2007 by Central Pollution Control Board (GOI), weeds, insects and diseases cause 28, 23 and 25% losses to food grains respectively. Losses during storage was 10%. Rodents' share of crop loss was 8%. The present article discusses the problem of rodents in Indian agriculture.

Besides, being a serious threat to our food production, several rodent species are known to spread many zoonotic diseases to humans and its livestock, threatening health security as well. Plagues, leptospirosis and leishmaniasis are the common diseases transmitted by rodents.

WHAT ARE RODENTS?

Rodents have been living with us since times immemorial. They appeared on earth much before human. According to Hindu mythology rats are mount of Lord Ganesha, the auspicious protector and well-wisher of all good acts. It is enlightening that Aryan's prayer to Ashwin quoted in 'Vedas' says "O Ashwin! Kill the burrowing rodents which devastate our food grains, cut their heads, break their necks, and plug their mouth so that they can never destroy our food. Rid mankind of them. Likewise, the 'Bharat Puranas'. Has also mention of rodent problem which says "desert your dwellings as soon as dead rats are seen in the house" probably referring to 'Plague', the black death spread by rats.

Rodents are vertebrates belonging to order Rodentia in class Mammalia. There are 103 species of rodents reported from India, however only a dozen or more are listed as pests of crops, however a pest complex of 2-4 species occur in any agro ecosystem causing 5-15% damage to standing crops in fields and threshing floors. When the food grains are rought to stores or godowns the commensal rodents (2-3 species) are ready to cause losses by directly feeding on them and also by contaminating with their fecal pellets, urine and hairs making then unfit for human consumption.

Thus, besides causing losses to food production and storage, the rodents are known to transmit several deadly diseases to humans and its live stock. World dat indicates higher number of rodent species in South East Asian continent, as the turnover of rodents is much igher in tropical regions than in other parts.

WHY RODENTS ARE PESTS?

Rodents are serious pests because of being mainly herbivorous, and presence in large numbers due to several biological, behavioural and adaptatability for successful living in agricultural ecosystems. The name rodent is derived from Latin 'rodere' + dent because all rodents possess a pair of ever-growing chisel shaped incisor teeth in each jaw adopted for gnawing. The incisor teeth grow @ 0.4 mm/day. They do not have canine teeth leading to a sizable gap between incisor and cheek teeth called as diastema. The cheek teeth are adopted for vegetal food. The incisors help rodent to gnaw through any type of hard and soft matter (edible or otherwise). The edible matter is taken in and grinded by molars, whereas the non-edible matter is thrown out through diastema.

Rodents are highly adapted to a variety of habitats and crop fields and food grain stores provide most conducive environments for field and commensal rodents, respectively. The gnawing habit of rodents owing to ever growing incisors and their vast breeding potential make the rodents one of the most destructive organism. Besides rodents possess a great feeding potential as they generally consume 5-10% of their body weight on daily basis. The agricultural fields serve as a highly productive rodent habitat and crops like sugarcane, rice, wheat, groundnut and fodder crop serve as an ideal habitat for rodent pests. Similarly threshing yards located near crop fields too act as an excellent abode for food and shelter of rodents.

Following biological characteristics of rodents make them highly successful animal and thus a serious pest in Indian agriculture

- Rodents have well developed sense of smell, hear and touch.
- Are colour blind but can distinguish shades.
- Possesses ever growing incisor teeth (@ 0.4 cm/day) which are very sharp and chisel shaped.
- Very good climber and swimmers.
- Use fixed run ways.
- Mostly nocturnal.
- Omnivorous and cannibalistic.
- Neophobic and neophillic.
- Cannot vomit.
- Can adapt to a variety of situations.
- Field rodents mostly burrowing type, fossorial, a few like squirrels are arboreal.
- Life span: 1-2 years.
- Very fast breeders: Young ones attain puberty in 6-16 weeks; Oestrous cycle: 3-7 days; Gestation period 18-30 days; Litter size: 1-22 (6-10 are very common); Breeding potential 800-1200/ pair/year.

CROP FIELDS IDEAL FOR RODENTS

Provision of good nutritious food and safe shelter is the only requirement of any animal for successful survival. In India we have three cropping seasons, kharif, rabi and summer season. The crops are taken according to soil fertlity, availability of irrigation water, and climate suitability. Thus, only one or two plant community dominates in the crop fields, which provide regular energy ich food and shelter to native rodents on a continuous basis. Rodents take advantage ofseasonal availability of abundant food and during lean season are able to overcome the situation due to their vast eco-biological and behavioural adaptations, by shifting their habitat to other nearby places. This makes rodent as a serious pest. Thus, agricultural fields serve as a highly productive rodent habitat. Among various crops, sugarcane, rice, wheat, groundnut and fodder crop fields serve as an ideal habitat for rodent pests in India.

RODENT PEST SPECIES

As discussed above about a dozen species are regarded as pest in agriculture, however a pest complex of 2-4 rodents occurs in any particular agro-climatic region. The lesser bandicoot rat, *Bandicota bengalensis* is the most predominant rodent pest species and is well distributed in crop fields and residential areas all over the country, except the extreme hot arid regions.

Other species of national importance in the fields are soft furred field rat, *Millardia meltada*, Indian gerbil, *Tatera indica* and Field mouse, *Mus booduga*. In arid areas of western Rajasthan Indian desert gerbil, *Meriones hurrianae* and hairy footed gerbil, *Gerbillus gleadowi* attain pest status in rain-fed crops. Similarly, in plantation crops viz., coconut, coca, arecanut, *Rattus rattus* wroughtoni is a major problem. Among squirrels, *Funambulus pennanti* infest fruit orchard in North India and *F. palmarum* and *F. tristriatus* is a pest of fruits and plantation crops and spices in South India. Indian crested porcupine, *Hystrix indica* is regarded as pest of tuber crops. Another species, *Nesokia indica* has also been listed as pest of irrigated crops, fruit orchards and forestry plantation in Northern India. The two most common commensal rodents, viz., *Rattus rattus* and *Mus musculus* are a serious problem in storage and godowns but during last few years these have also been reported in crop fields in different regions. *Rattus nitidus* is considered as a crop pest in higher reaches of the Northeastern hill region. A list of predominant rodent species and their major habitat and distribution are given in Table 1. Rodents as such have no particular preference for any crop/commodity, however a broad association with crops/ regions have been noticed (Table 2).

Table 1. Predominant rodent species, their habitat and distribution

SN	Name of the species	Major Habitat	Distribution
1	*Bandicota bengalensis*	Crop fields and stores, godowns, ware houses poultry farms	All over India except extremes of arid zone
2	*Tatera indica*	Crop fields and grasslands, rural poultry farms	All over India (Except hills)
3	*Millardia meltada*	Crop fields and grasslands	Rajasthan Gujarat, Punjab, Haryana, Central and southern India
4	*Mus booduga*	Crop fields	All over India
5	*Meriones hurrianae*	Crop fields, grasslands	Rajasthan, Gujarat, Haryana and Punjab
6	*Rattus rattus*	Houses, godowns, ware houses	All over India
7	*Rattus rattus wroughtoni*	Plantation crops	Southern India
8	*Mus musculus*	Houses, godowns, ware houses also in Croplands	Crop fields in Punjab, Haryana Rajasthan All over India as commensal species

9	*Rattus norvegicus*	Sewers	Major Port cities
10	*Funambulus pennanti*	Near human habitations, gardens, orchards	Northern India up to northern Karnataka
11	*Funambulus palmarum*	Near human habitations, gardens, orchards	Southern India
12	*Funambulus tristriatus*	Forests and plantation crop orchards in Western Ghats	Western Ghats
13	*Hystrix indica*	Tuber crops and orchards and forest areasners hilly tracts	All over India

Table 2. Major rodent species associated with crops

SN	Crops	Associated rodent species
1	Pearl millet, Sorghum, Maize etc	*Meriones hurricane, Tatera indica, Millardia meltada, Bandicota bengalensis* and *Mus booduga*
2	Rice	*Bandicota bengalensis, Mus booduga* and *Millardia meltada*
3	Wheat, Barley	*Bandicota bengalensis, Millardia meltada, Tatera indica* and *Mus booduga*
4	Ground nut	*Bandicota bengalensis, Millardia meltada, Tatera indica* and *Mus booduga*
5	Sugarcane	*Bandicota bengalensis, Mus booduga, Tatera indica* and *Nesikia indica*
6	Cotton	*Bandicota bengalensis, Millardia meltada, Tatera indica* and *Mus booduga*
7	Oilseeds and pulses	*Bandicota bengalensis, Millardia meltada, Tatera indica* and *Mus booduga*
8	Plantation crops (Coconut/ cocoa)	*Rattus rattus, Funambulus palmarum,* and *F. tristriatus*
9	Stores and godowns	*Rattus rattus, Mus musculus* and *Bandicota bengalensis*

NATURE OF RODENT DAMAGE

Being herbivore, choice of food for rodents is unlimited. No crop is spared by these tiny vertebrates at any stage of its growth. Extent of rodent damage to crops largely depends upon the (i) species involved (ii) location and stage of crop (iii) population of the pest (iv) availability of crop and (v) physical environment. Perusal of data on the extent of damage indicates that a plant, a seed, a fruit or its produce in any form is always exposed to the vagaries of rodent depredations. These are just pre harvest losses, however the losses inflicted between sowing and germination, (when the rodents pinpointedly feed on the sown seeds, because of their seedvorous behavior), are never accounted. The nature and type of rodent damage are;

- By, picking the sown seeds before germination.
- By feeding on the plants by cutting the young seedlings, leaves, stems, inflorescence, green and mature pods.
- By hoarding the food material in their burrows.
- Through extensive burrowing leading to soil erosion, damage to water channels, dams etc.
- Through consumption, spoilage and contamination of harvested crops in threshing floors and stored grains in storage.
- Structural damage to stores godowns etc

RODENT INFESTATION PATTERNS

Rodent's infestation patterns in crop fields generally depends on the stage of the crop. In one our studies in arid pulses, which may be considered as a case study. In this study we observed that during May-June, which is lean period for rodents, they mostly thrive on the roots/rhizomes of various desert vegetation. As soon as the seeds are sown the native rodents immigrate to the crop fields and settle on the bunds and pin pointedly pick the sown seeds causing poor germination. Considering the stresses of low moisture regimes in arid regions, the farmers generally maintain a higher seed rate for these rain fed crops. This practice helps them tide over the problem of rodent damage to sown seeds also. The region is mainly inhabited by desert gerbil, Meriones hurricane, which a diurnal rodent and digs large number of burrows. Just after the land preparation for sowing, the live burrow density in the crop fields was very low i.e. around 5-20/ha that to in peripheral regions of the crop fields, whereas the same was 62-95/ha in the surrounding fallow lands. With the initiation of germination and further vegetative growth of the crops the pest rodents from surrounding fallow lands enter the crop fields and initially inhabit the peripheral regions (5-10m strip) which increase to 158-169/ha at 15- 30 days old crop. At pod formation and maturity stage, the pest population moves towards central portion of the fields and gets distributed throughout the fields. At this stsge, the gerbils get good food as well as safe shelter inside the crop. During monsoon season the breeding activity of the desert gerbils attains a peak that coincides with the flowering/ fruiting stage of the kharif pulses. Cessation of inter culture operations, at pod formation and maturity stages facilitates the rodent to settle in the fields and cause extensive damage to pods. Therefore, the pest rodents though pester the arid pulses throughout the crop growth period, their infestation attains serious concerns at pod formation / maturity stage. Farmers also realize the severity of the problem at this stage. Similar infestation patterns are observed in most of the arable crops.

LOSSES DUE TO RODENTS

1. Arable crops: Rodent damage to food crops, sugarcane pulses and oilseed in India has been well documented (Table 3). Cereals like wheat and rice suffer a pre harvest rodent damage in the range of 5-15% in different regions. Rodent problem can be seen from another dimension also which reveals that a loss of 4.3% panicles (equivalent to 1.11 q/ha of wheat) and 4.64% in rice panicles (equivalent to 1.72 q/ha of coarse rice) after harvest on threshing floor. Sugarcane is highly vulnerable to rodent depredation experiencing up to 31.0% direct damage in different regions of India. Rodent attack to sugarcane not only decreases the crop yields but also adversely affects sugar recovery to the tune of 25%. The damaged canes develop serious fungal and bacterial infections leading to rotting of affected canes. Sugarcane being a long duration crop acts as a reservoir habitat for rodents and rodents become a perennial problem not only to sugarcane but to rice/ wheat crops grown as cropping system mode. Five-year long studies from Punjab (2002-07) indicated that the rice and wheat crops experienced 0.2-3.0 (mean; 1.13) and 0.5-15.2% (mean: 4.21) rodent damage under monoculture situations, however when these crops are grown with sugarcane in the surroundings the damage increases to 5.1 in rice and 10.8% in wheat. The pulses like mung bean and moth bean suffer almost 3-6 % pod damage in Rajasthan and Gujarat. Similarly cow pea suffers 4-18% rodent damage. Ground nut, an important oilseed crop also serves as an ideal rodent habitat where rodents registered 4-7% pod damage, besides hoarding 320g/ burrow. During out breaks (1976 and 1988-89) the ground nut suffered up to 85.42% damage in Saurashtra region of Gujarat. Other field crops like millets, sorghum and maize also suffer extensively due to rodent infestation. Classical example of rodent damage to peal millet (by *Gerbillus gleadowi*) was seen in Rajasthan where the gerbils caused complete damage and crops were to be re-sown in western Rajasthan. The vegetable crops are equally vulnerable to rodent damage. Cucurbits like cucumber, musk melon, ridge gourd and sponge gourd suffer up to 10% rodent damage. Among solanaceous vegetables, rodents inflict a fruit damage of 11.1-37.3% (Punjab), 19% (Rajasthan), 2.6-35% (Gujarat) and 5% (Karnataka) to tomato. In arid regions the vegetables experienced 4.4-19% damage by desert rodents.

The hoarding behavior of *B. bengalensis* further intensifies the rodent problem. The intensity of losses varies from region to region. Earliest report of such a loss was reported when over 600 rice ear heads were recovered from one bandicoot burrow. Most of the bandicoot burrows when excavated contain hoarding material to the tune of 500g to 1 kg/ burrow.

2. Fruit/plantation crops: Rodent damage to apple, peach, pecan and plum in Himachal Pradesh was found to be 17-40, 2-7%, 1.6-6.7 and 1-2%, respectively. Similarly, ripe fruits of pomegranate are devoured to the extent of 17-22% by squirrels in Rajasthan. Date palm is another highly vulnerable crop for squirrel attack causing 18-20% fruit damage. Ber, an important fruit crop in arid regions suffers maximum damage (up to 80%) in nurseries. Among plantation crops, coconut and cocoa are extensively damaged in south India to the tune of 21-28.5% in Kerala, 12-15% in Karnataka, 4.5-55% in Lakshdweep and 4-1-5.8% in Andaman and Nicobar Islands in coconut and 50-60 % damage to cocoa in Tamilnadu and Kerala. The oil palm cultivation suffered a serious setback in Andaman and Nicobar Islands during 1980s, due to infestation of *R. rattus* as the crop suffered 10-29.5% damage to seedlings and saplings and 57.3% fruit damage.

3. Afforstation plantations and Grasslands: Rodents extensively damage the forestry plantations by debarking and or slicing of tress. The short-tailed mole rat, *N. indica* was reported to slice the root of arid zone plantation to the tune of 4.4-10 per cent. In arid regions, where vast stretch of sandy waste/pasture lands is available the Indian desert gerbil, M. hurrianae causes havoc to pasture grasses. In one of the earlier reports (1970s) from a pasture in Bikaner, a density of 477 gerbils/ha was noticed. At this population level, the feed requirements of gerbils aws 1040 kg/ha feed, whereas the annual productivity of the land was 1210 Kg/ha only, that means almost nothing was left for desert livestock due to heavy population of gerbils.

Table 3. Rodent damage and species infesting field crops in India

Crop	Stage	Damage (%) YL (yield loss Kg/ha)	Species	State/ region
Wheat	Seedling to Maturity Pre harvest	5.9 18.7-21.3 3.9-5.2 8.0-10.	Mh, Ti, Rm Bb, Ti Bb	Rajasthan Rajasthan Punjab Uttar Pradesh
Rice	Pre harvest Pre harvest Grain formation	1.1-17.5 98-213kg/ha	Bb, Rm Bb Bb, Mm,	Punjab Uttar Pradesh Karnataka

	Harvest stage	9-10 17.56	Mb Bb, Mb	Andhra Pradesh
Pearl millet	Seeling Milky, Grain	3.0-12.0	Gg, Ti, Mh Bb, Ti, Mm	Rajasthan Gujarat
Maize	Cobs Cobs Seedling Cob formation Cobs	9.8 9.1 10.7 7.0 5.0	- Rn, Bb - Bb, Ti Bb, Ti, Mm	Himachal Pradesh Meghalaya Punjab Karnataka Gujarat
Groundnut	Plants & Pods Pod setting Pod maturity Harvesting Peg formation	3.9-19.0 4.5 6.9 7.3 30-40	Ti, Rm, Bb, Mb, Mm Bb, Ti Mm Bb, Ti	Punjab Gujarat -do- -do- Karnataka
Cotton	Bolls Damaged bolls	3.2-23.2 4.0-6.0	Ti, Rm Bb, Ti, Mm	Gujarat Gujarat
Sugarcane	Partial damage to canes Dried canes Without lodging With lodging	 2.1-21.6 3.2 6.8 18.9	 Bb, Ti, Rm, Mm - Ti, Bb Ti, Bb	 Punjab Punjab Uttar Pradesh Uttar Pradesh

Ti-*Tatera indica*, Rm-*Rattus meltada*, Bb-*Bandicota bengalensis*; Mh-*Meriones hurrianae*; Mp-*Mus platythrix*; Rr-*Rattus rattus*; Ge-*Gollunda ellioti*; Mb-*Mus booduga*; Mm- *Mus musculus*

4. Soil conservation: Reports of damage to water channels, dams, and other infrastructures bedcause of extensive burrowing by rodents can be frequently seen in media reports. *Bandicota bengalensis B. indica* and *Nesokia indica* are extensive burrows and many times cause such damages that cannot be quantified. In one of the earlier studies from CAZRI, revealed that the Indian desert gerbil, *M. hurrianae* a diurnal rodent digs large number of burrows. In one of the counts, up to 14000 burrows in a plot of 100x100m^2 were recorded. Extent of burrowing by the species can loosen 61,500-1,61,000 kg soil/day/km^2 in cultivated field in arid regions which can be easily blown away by high velocity winds causing problem of desertification and soil erosion.

5. Other sectors: Many other economic sectors suffer greatly due to rodents. Poultry farms provide a very favourable habitat where rodents maintain large populations. Through burrowing, nibbling and gnawing, feeding, urination, defecation and extensive movements, rodents damage and contaminate the poultry farm environments and causing severe economic losses. Rodents are also known to spread several diseases among birds and to poultry keepers. Burrowing and damage to structures increases the maintenance costs of farms. Rodents, especially the commensal ones viz., R. *rattus, M. musculus* and *B. bengalensis* are also regarded as serious menace in many other sectors like air ports, telecommunication, railways, IT, Food and beverages industries, etc. There are no scientific reports from India as such about the extent of damage to many of these sectors, but simple nibbling/ gnawing of telecom Fibre optic cables by native rodents may cause immense losses.

RODENT OUTBREAKS

Population explosion of rodents leading to outbreaks has also been reported in many regions of the country. Rodent outbreaks in Northeastern hill regions (Mizoram, Arunanchal Pradesh, Manipur etc.) leading to famine have been experienced during 1880-83, 1910-12, 1928-29, 1958-59 and 1976-77. Rodent damage to rice, maize and other crops reached to the tune of 75-90% in these years. This outbreak is attributed to the flowering of certain bamboo species (*Bambusa tulda* and *Melocanna bacciferra*) in the region. It is locally believed that feeding of bamboo seeds enhanced the reproductive ability of native rodents causing severe pest outbreaks. Records of rodent out breaks vis a vis bamboo flowering, leading to fanines have been well documentd from Mizoram (Table 4). The 48 years of bamboo flowering cycle is very clear, it is almost 30 years between Thingtam and Mautam and 18 years between Mautam and Thingtam. Next cycle may be experienced during 2023- 24. The last mass flowering of *M. bacciferra* in the aws observed during 200509-08. The Himalayan rat, *Rattus nitidus* and some forest dwelling species like *Rattus sikkimensis*, *Niviventer niviventer*, *N. fluvescens* etc are the major species responsible for the outbreak.

Table 4. Periodic bamboo flowering and rodent outbreak in Mizoram

Bamboo species in flower	Period	Types
Bambusa tulda & Dendrocalamus longispathus	1880-1884	Thingtam
Melocanna baccifera	1910-1912	Mautam
Bambusa tulda & Dendrocalamus longispathus	1924-1929	Thingtam
Melocanna baccifera	1958-1959	Mautam
Bambusa tulda & Dendrocalamus longispathus	1976-1977	Thingtam
Melocanna baccifera	2005- 2009	Mautam

Large-scale devastation of crops has been reported from other regions also. For example, rodent upsurge in Gujarat and Rajasthan during 1901-02;

1913-14; 1970-71; 1975-76 and 1997-98. In South India too rodent outbreak, as evident from upsurge of plague was recorded in1826, 1878-79, 1901-02 and 1913-14. Rodent outbreaks recorded in Southern India viz., Cauvery Delta (1994-2001), Godawari Delta (1997-98 and 2001) and Pondicherry (1994). Saurashtra region of Gujarat too suffered heavy devastation to groundnut, wheat, gram and cotton crop due to rodents' outbreak in 1990-91. Sudden upsurge of rodent population leading to outbreak may be due to (i) prolonged dry spell followed by heavy rains in Saurashtra region (1990-91) (ii) failure of monsoon in preceding years in Cauvery delta (1994&2001) (iii) flash floods in Godawari delta in 1997-98 and 2001 and/or (iv) flowering of bamboo in NEH region.

RODENTS AND PUBLIC HEALTH

Rodents are known to spread 31 zoonotic diseases to humans and animals. The word zoonoses has been derived from the Greek words zoon "animal" and nosos "ailment'. Thus, A zoonosis is any disease or infection that is naturally transmissible from vertebrate animals to humans. Zoonosis may be bacterial, viral, ricketsial, parasitic etc.

They are also reported to transmit 11 documented and 12 non documented hanta virus diseases, however no indigenous hanta virus has been reported from India so far. Some human diseases spread by rodents are plague, salmonellosis, rabies, tularemia, leptospirosis, amoebic dysentery, typhus (scrub and murine), jaundice, trichinosis, lymphocytic choriomeningitis, leishmaniasis etc. Also, they transport and host ecto-parasites, like mites, lice, fleas, and ticks. Some of the common zoonotic diseases transmitted by rodents are given in Table 5.

Table 5. Rodent borne diseases

SN	Rodent borne Diseases	Etiology	Reservoir	Vector
1	Plague	*Yersinia pestis*	*T. indica, B. bengalensis R. rattus*	*Xenopsylla cheopis X. astia, X. brasiliensis*
2	Kyasanur Forest Disease (KFD)	KFD Virus (Gen. Flavivirus)	Small Rodents	Ticks: *Haemaphysalis spinigera Ornithoros Chiropterphila*
3	Rocky Mountain Spotted Fever	*Rickettsia rickettsia*	Domestic and wild rodents	*Dermacentor andersoni*

4	Boutonneuse Fever	*Rickettsia conori Rickettsia sibirica Rickettsia australis*	*Rattus* spp.	-
5	Scrub Typhus	*Rickettsia tsutsugamushi*	*Rattus* spp.	Mite: *Leptotrombidium* Spp.
6	Chagas Disease	*Trypnosoma cruzi*	Rodents	Triatoma bugs
7	Cutaneous Leishmaniasis	*Leishmania major*	*Meriones hurrianae*	*Phlebotomus salehi*
8	Leptospirosis	Leptospira sp, a bacterium	Rats, dogs, live stock	
9	Murine typhus	*Rickettsia typhi* (mooseri)	*Rattus norvegicus R. rattus, R. exulans*	*X. Cheopis*
10	Q Fever	*Coxiella burnetii*	*Rodents*	-
11	Rickettsia Pox	*Rickettsia akari*	*Mus musculus*	Mite: *Liponyssoides sanguineus*

Plague is one such deadly disease which has claimed over onen crore human lives from 1896-1996 in India. Latest plague epidemic during 1994 in Gujarat resulted in 54 deaths out of 876 reported cases. Several sylvatic plague foci have been recognized in India in Jammu and Kashmir, Himachal Pradesh, Uttarakhnd, Maharashtra, Andhra Pradesh, Karnataka and Tamil Nadu states. Rodents are primary host of plague bacteria (*Yersinia pestis*) which is transmitted to humans by oriental flea (*Xenopsylla cheopis*) an ecto-parasite of rodents. Indian gerbil, *Tatera indica* is considered as reservoir of plague bacteria as the gerbils are susceptible to infection but resistant to the disease.There exists possibility of plague infection present in *T. indica* (the reservoir species) to get transmitted to commensal species like *R. rattus* and peridomestic, *B. bengalensis* which are highly susceptible species through fleas. Leptospirosis is another zoonotic disease which is spreading to humans in different parts of the country. The International Leptospirosis Society opined that more than 100,000 severe cases of letospirosis occur annually worldwide. In India, Andaman and Nicobar Islands, Gujarat, Kerala, Orissa, Maharashtra and Tamil nadu are the endemic states where this disease is quite prevalent. Besides rodents, cattle, pigs, dogs and cats are also major hosts of bacteria, Leptospira ecterrohaemorrhagiae, which is the common sero-group. Among rodents, *R. norvegicus, R. rattus* and *B. bengalensis* are associated with this disease. The organism lives in kidney of animals and is thrown outside through urine. The man gets the infection through abraded skin coming in contact with infected water. People working in rice fields and other water logged areas are always vulnerable to the infection. Several cases of Leptospirosis have been reported in recent years from Gujarat, Kerala, Orissa and Maharashtra.

A case study of managing rodents for protecting the crops as well as Leptospirosis in Gujarat: Southern Gujarat suffered a severe leptospirosis problem in 2008-09. Implementation of rodent management campaigns in the affected districts proved very effective not only in managing rodent problem in agriculture, but also in reducing incidence of leptospirosis. It was a perfect case study for integrating Agriculture and Health Department in managing the pest/ vectors for enhanced crop production and ensuring health problems. During 2009, Departments of Agriculture and Public Health of Gujarat State got the scientific support of National Plant Protection Training Institute, (Ministry of Agriculture, Government of India), Hyderabad and All India Network Project on Rodent Control, ICAR-Central Arid Zone Research Institute, Jodhpur in planning, implementation and monitoring of the anti-rodent campaigns. To achieve this, State Level and District level Workshops were conducted. The management planning was made considering (i) specific areas/villages with the prior disease incidence, (ii) time of control operations before the onset of monsoon, (iii) timely procurement of inputs for control operations and (iv) community participation for effective prevention of the infection to humans as well as animals. Community level anti rodent campaigns were undertaken by using bromadiolone, a second-generation anticoagulant baiting covering both sugarcane fields and adjoining residential premises. More than 2000 kg of bromadiolone, was used. The results presented in Table 6 indicated that cases of Leptospirosis were only 61 per cent in the campaign implemented villages during 2009 compared to 2008. Further, the rodent damage to sugarcane was reportedly reduced up to only 5% as compared to 15-20% normal cane damage. It was also observed that the annual rainfall was 91% of average during 2009 in these districts, while it was 100 per cent in 2008. This deficit rainfall of 9% might also be one of the contributing factors for the reduction in the cases.

Leishmaniasis, another zoonotic disease is transmitted by the bite of sand flies infected with a protozoan, *Leishmania* sp. One of its species, *L. tropica* is confined to hot dry north-western regions of India, is endemic in the western Thar deserts of Rajasthan. Sporadic cases have also been reported from Punjab, Delhi, Haryana and Gujarat. It causes *Cutaneous Leishmaniasis*. Both dogs and rodents serve as the zoonotic reservoir for CL in the Thar Desert. In Bikaner, in dogs, a major reservoir, incidence rates of 6.8% and 6.12% were recorded during 1985 and 1999, respectively.

Table 6. Impact of rodent control campaigns on incidence of leptospirosis in South Gujarat

Name of the District	Total no. of villages	No. of villages covered	Area treated (ha)	Bromadio-lone used (kg)	No of cases of Leptospirosis in		Reduction of Leptospirosis incidence (%)
					2008	***2009***	
Surat	407	43	2102	784	220	78	64.55
Tapi	148	15	1942	777	133	40	69.92
Navsari	397	18	442	177	131	43	67.18
Valsad	178	38	1235	494	74	54	27.03
Total	1130	114	5721	2232	558	215	61.47

CONCLUSION

The Global climate change as evident from increase in temperatures and changing rain fall patterns are likely to accentuate the rodent problem further as these tiny vertebrates would successfully adapt to any such changes. The change in cropping patterns (high value crops replacing the traditional crops) and farming system approach (growing perennials and annuals together) may prove more conducive for rodent life. The introduction of pressurized irrigation systems (sprinklers and drips) provides very favourable microhabitats to native rodents and rodent damage to drip and sprinklers systems are more frequently reported these days. Poly house/ protected agriculture are also threatened by rodent attack. *B. bengalensis*, the most predominant and destructive rodent pest of the country is spreading its territory and is showing its destructive potential in new areas like, arid western arid and north eastern hilly regions. Thus, the challenges from pest rodents are manifold and therefore require immediate attention of policy planners, scientists, extension officials and farmers for managing the pest rodents effectively for increased crop production and productivity. Effective management of rodents in fields and commensal situations can also reduce burden of rodent borne disease as well. Our Gujarat experience further strengthen the idea of managing pest/ vector rodents for food and health security.

BIO-ECOLOGY OF RODENT PESTS

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Rodents are highly evolved and probably the most adaptable mammals and can cope up with newer environments, new foods, and adjust to new associates with a striking swiftness. Their sense of olfaction is acute. They are possibly able to perceive sounds travelling through solid medium due to hypertrophied bullae tympanica and to discriminate between harmful and harmless sounds and foods. The knowledge of their ecological, biological and ethological aspects is essential for their management in fields as well as in commensal situations.

REPRODUCTION AND GROWTH

Most of the rodents breed round the year, however their reproductive rate may be low in some months and high in others. Knowledge of a basic understanding of reproduction and its seasonal variation in rodents is important and highly useful in planning control procedures.

The female reproductive system consists of vagina, uterus, ovaries etc. Externally, young females resemble young males since females have a structure (clitoris) homologous to the male penis, since the vaginal opening in sexually immature females is closed (imperforate) and not easily seen. The sex of young animals can he determined by noting the distance between the penis or clitoris and the anus. The distance is shorter in females and longer in males. Also, even in young males, the internal shaft of the penis can be everted by applying a slight pressure.

Before the age of sexual maturity in female rodents, the vagina becomes open (perforate). Most female rodents attain sexual maturity from 5 to 9 weeks of age. After copulation and fertilization occur, the small embryo implants itself in the wall of the uterus. As the embryo grows a special organ called the placenta develops, which provides for a close association between the maternal and embryonic blood vessels. In this way the embryo receives nourishment for growth. At birth the placenta is shed away from the uterus and expelled. At the site of the former attachment of the placenta to the uterus, a placental scar is formed, which in most rodent species lasts for life. Placental scars appear as black spots on the uterus. The total number of scars on a female is equal (or nearly equal) to the number of young she has produced.

In young male rodents, the testes are not visible externally as they are in the abdomen. Before sexual maturity, the testes descend into a sac (scrotum) below the penis.

The female of most rodents is receptive to copulation only for about 12 hours in every 3 to 7 days. This period of receptivity is known as estrus. In most rats and mice, the female may be receptive to copulation within a few hours after giving birth. This is called post-partum estrus. Normally in the gestation period, or time from fertilization to birth of young in rodents' range between 19-23 days.

There is a correlation between the length of gestation period and the developmental condition of the young mammal. Those with short gestations have altricial young (usually hairless, eyes and ears closed, unable to walk), while those with long gestations have precocial young (born fully haired, eyes and ears open, able to walk in a few hours). As a broad rule, small mammals have higher postnatal growth rates than do large mammals: that is, a small mammal will attain adult weight at an earlier age than a large mammal.

The growth and development of Rattus provides an example of rapid development in a small mammal. At birth young Rattus are naked and have the eyes and ear openings closed. There is little change in appearance for the first two days. On the 3rd day the dorsal surface starts to darken, fine short hairs can be seen, and weak crawling movements are observed. Pigmentation of the nose, back and tail become evident on the 5th day. During the next few days the young become fully haired. The lower incisors erupt on the 9th day and the uppers on the 10th day. The eyes and ear channels open on the 15th to 16th day. Supporting the body on the legs and walking is evident from the 10th day onward.

By the 17th day the young climb agilely, run rapidly and give all the appearances of an adult. By the 20th day, they are fully independent and leaving the nest for short trips. They are fully weaned and eating solid food by the 25th to 28th day. By three or four weeks they are independent and leave the maternal nest. Young of Bandicota bengalensis approach adult size in about 3 months, mice in about 6 weeks.

POPULATION GROWTH

Short gestation periods, post-partum estrous condition, large litter size and rapid maturation of the young are the characteristics of the rodent populations which lead to their rapid growth. The rapid increase in rodent populations make them the world's most important pest species.

Generally, a rodent population which undergoes a reduction in size (as from poisoning) recovers slowly at first and then at an increasingly faster rate. When it approaches the carrying capacity of the environment because of limitation of food, water and shelter, growth slows down and the population tends to level off. In an unchanged environment, the population would be expected to remain at essentially the same level but in practice it tends to fluctuate in size, around the carrying capacity of the environment.

BREEDING

In most of the bio- climatic zones of India, the rodents breed all the year round but exhibit peak reproductive activity during monsoon and winter. This activity is at its minimum during summer month when climatic conditions are not conducive and the food is scarce.

The Crested porcupine, *Hystrix indica* litters from March to December and the litter size varies from 1 to 3. The Northern palm squirrel, *Funambulus pennanti,* breeds from March to December in northern India, peak littering was observed during March-April and July-September. Litter size varies from 1 to 5.

The Indian gerbil, *Tatera indica* breeds all the year round in northern India with peaks in monsoon in the desert region. The litter size in the species varies from 1 to 12.

The frequency of pregnant desert gerbil, *Meriones hurrianae* swings between 6 to 26 per cent during the year with a continuous higher rate during the spring, monsoon and post- monsoon seasons. The litter size varies from 1 to 9.

Pregnant house rats, *R. r. rufescens* were found every month of the year at Jodhpur and the litter size varied from 4 to 7. Littering of *Rattus meltada pallidior* in captivity in Punjab was during March to May and July to October. In Rajasthan, in crop fields its reproductive activity continued all through the year with a peak spell of pregnancy continuing from spring to monsoon. The female Cutch of Rock-rat *Rattus cutchicus cutuhicus*, was found to be pregnant from March to October in Rajasthan.

Mus musculus inhabiting crop fields breed all the year round. At Jodhpur also the mouse, collected from residential premises littered all the year round with peaks during the winter and spring. The number of embryos per pregnant female fluctuated from 2 to 15 (av.5.34).

The little field mouse *M, booduga*, also breeds though out the year with a low activity during summer. Its litter size varies from 2 to 11. *M. platythrix* also breeds all through the year except summer with a litter variation from 2 to 12.

The bandicoot, *Bengalensis bengalensis* breeds all the year round with a litter size of 2 to 14. *Nesokia indica* around Delhi breeds during January to March and August to October, the litter size varied from 2 to 5 with an average of 3.0.

Most of the rodents which inflict losses to agricultural produce and other economic commodities breed all the year round with retarded reproductive activity during summer months. This season is therefore considered to be appropriate for taking up massive control programmes.

Table 1. Litter size of Indian Rodents (Prakash and Mathur, 1987*)

Rodent Species	**Litter Size**	
	Range	**Average**
Hystrix indica	1-3	1.45
Funambulus Pennanti	2-5	3.8
Gerbillus nanus	2-3	2.33
Gerbillus gleadowi	5-6	5.5
Tatera indica	1-9	4.8
Meriones hurrianae	1-9	4.4
Rattus rattus wroughtoni	1-9	-
R. rattus brunneusculus	2-10	5.5-6.5
R. rattus rufescens	1-9	-
Rattus cutchicus australis	1-4	-
Rattus c. cutchicus	2-8	4.0
R. meltada pallidior	4-10	5.9
Rattus m. meltada	3.9-6.1	5.4
R. gleadowi	2-3	2.3
Mus musculus humourus	1-5	-
Mus m. tytleri	1-8	-
Mus m. bactrianus	2-15	5.3
Mus booduga	2-12	4.5
Mus cervicolor phillipsi	2-6	4.4
Mus platythrix platythrix	4-7	-
Mus p. sadhu	2-12	7.6
Golunda ellioti gujerati	5-10	6.6
Nesokia indica indica	8-10	-
Bandicota bengalensis	2-13	6.2
Bandicota indica	1-4	-

*Prakash, I and Mathur, R.P. 1987. Management of Rodent Pests. ICAR, New Delhi. p133

POPULATION DYNAMICS

Rates of natality, mortality, immigration (movement into the population) and emigration (movement out of a population) combine to determine density. The interaction of these forces is population dynamics. Everywhere in country, there are seasonal changes in the environment which cause rodent density to vary greatly over the year. An understanding of population dynamics must include seasonal variation of birth and death rates. Each species shows a different pattern of seasonal variation. Even populations of a single species living in different climatic zones can differ in their population dynamics.

Population of squirrel, Funambulus pennanti, oscillates between April and October.

In the urban area of Bikaner (Rajasthan), the Indian gerbils, *Tatera i. indica* were randomly trapped alive every month for 12 months with two minor peaks during May –June and August-September were observed. The number of rodents per-night catch varied from 30 to 78.

In western Rajasthan, the population fluctuations of desert gerbil (*M. hurrianae*) on the basis of live burrow count method was recorded higher during winner. It continued up to spring and their number declined during summer. The rise in population of merino gerbil during winter was attributed to the higher breeding rate as well as to their superior survival rate in monsoon which was influenced by the availability of green food.

Millardia (Rattus) meltada, the soft- furred field rat common in the crop fields in India. In Punjab its population were 1.66 (March) to 4.1 (October) with an average of 2.54. Peaks in the numbers of this species in the crop fields of south eastern Rajasthan were during winter.

In agricultural land the population of *Mus platythrix platythrix* was minimal in summer (2.2) and maximum in winter (6.6). In the Rajasthan desert, the populations of *M. p. sadhu* and *Mus cervicolor philipsi* were low during summer and high during winter.

The ecology of bandicoot *B. bengalensis* was studied in fields with natural vegetation in the district of 24-Paraganas (West Bengal). They were 108 per hectare in November and 446 in December with a burrow-occupancy rate of 5.4 and 9.3 in the respective month. These observations indicated a very steep rise in their population within a month. In the urban habitat, in food grain godowns, an average of 0.78 rat per m2 of floor space however, it varies from 0.1 to 0.4 per m2 in godowns at Calcutta. In Bombay, however, a steady number of *B. bengalensis* has been reported over various months of the year

These studies clearly indicated that on an overall basis, the rodent population is low during summer, and increases during winter and spring when the crops are field.

BURROWS

Most of the rodents of economic importance inhabit burrows. The subterranean mode of living by rodents not only provides them home but also assures some protection from predators and helps them in thermoregulation. Usually diurnal rodents excavate complicated burrows in several tiers in the earth, since they unload the hypothermia developed due to continuous exposure to the hot environment, by visiting a cooler environment inside burrows.

Nocturnal rodents which do not come out of their burrows during the day therefore, construct simple, elongate burrows. During the breeding season or 'caching' period almost all the rodent species enlarge their burrow and excavate breeding or hoarding pouches to accommodate young ones or the food material, in addition, all the fossorial rodents maintain one or more bolt- run to escape the chasing predators.

Rodent control operation by fumigating the burrows is more successful in simple burrows, since the escape of poisonous is minimum, and the lethal concentration of gas is bolt up in simple burrows at much faster speed than that in complicated burrows, and the rodents are unable to escape.

FOOD HABITS

Most of the rodents are herbivorous, but prefer seeds, and occasionally feed upon insect and other animal food. It is, however, very difficult to study the species composition in their natural food for they chew the food to tiny particles and their identification from stomach contents or fecal pellets is a tedious task. The palm squirrel, *Funambulus pennanti*, consumes fruits, insects, insect larvae and bird eggs and a large number of locusts during the summer months when little vegetation or fruit is available.

The food of *T. indica* was composed of seeds during winter, and insects during summer. Stems, rhizomes and leaves were eaten all the year round. In the urban or rural habitats, near human dwellings *T. indica* more or less depends on man for its food. The desert gerbil chiefly thrives on seeds but during monsoon it switches over to leaves and shoots of green vegetation, and to insects during summer. During monsoon, it was observed to be a selective feeder, preferring only highly nutritive and palatable grasses, thus competing with livestock animals.

The food of *B. bengalensis* composed of mollusks, insects, arachnids and earth-worms, besides vegetable matter as revealed from its stomach content, *Rattus meltada pallidor* consume 87.7-97.7 percent plant parts of their natural diet, mainly wheat, and insects throughout the year in low proportion.

ACTIVITY PATTERNS

If the baiting programme for the control of rodents is in tune with their peak activity epoch, the intake of food as well as poison baits would be expected to carry lethal dose, as a consequence of which the control success will be superior to that when baits are laid at a time convenient to the operators. Broadly, the rodents can be grouped into two categories: diurnal and nocturnal. However, a number of nocturnal rodents when inhabiting an undisturbed habitat, venture out during day also. Likewise, certain diurnal ones alter their circadian rhythm chiefly to shun the climatic vagaries. During winter, the desert gerbil, *M. hurrianae* remains out of burrows throughout the day but during summer when it is too hot, its diurnal activity is altered to a bimodal pattern, about 3 hours early in the morning and 2 hours late in the evening.

The above ground activity period of *T. indica* during winter extended between 19.00 and 03.00 hours. Within this period, 2 major peaks of activity could be detected. Another nocturnal rodent the bandicoot exhibited a diversity in the activity pattern of male and female animals. The females had 2 daily peaks of activity, one in the early evening and another in the morning, like *R. rattus*, the house rat, but the males had a peak of activity in the middle of night in addition to peaks in early evening and morning.

HOME RANGES

Rodents, like many other mammals, follow a social hierarchy and are very well organized, particularly the species which are gregarious. The most common display of dominance is through the range of their movement known as home range. Each rodent possesses a home range which may or may not overlap that of others. The study of home ranges may apparently look that academic interest, but it has an important implication from the point of view of rodent control operations. *M. hurrianae* the desert gerbil, moves about in a specific area and the home ranges of various animals overlap each other and therefore if poison baits, during the control operation, are laid at a 10m interval in the field at least 2-3 gerbils will have a chance to feed upon a single bait station. In turn, considerable amount of labour and food grains will be saved by not laying baits in each and every active burrow.

Table 2. Home ranges and maximum distance travelled by some Indian Rodents (Prakash and Mathur, 1987) *

Rodent species	**Home range (Mean±SE)**	**Maximum distance travelled (Mean±SE) m**
Funambulus pennant	0.21±0.073 ha	65.61±4.80
Tatera indica indica	1912.5 m^2	60.38±9.35
Meriones hurrianae	154.7±24.63 m^2	18.46±1.50
Rattus meltada pallidior	1217 m^2	31.0
Mus musculus bactrianus	675±390 m^2	25.0
M. booduga booduga	1275±52 m^2	31.0
M. platythrix	-	22.5
Golunda ellioti	-	22.5
Bandicota bengalensis	945±515.8 m^2	-

*Prakash, I and Mathur, R.P. 1987. Management of Rodent Pests. ICAR, New Delhi. p133

DEPREDATORY BIRDS AND THEIR DAMAGE PATTERN IN DIFFERENT AGRICULTURAL AND HORTICULTURAL CROPS

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In India there are about 1364 species of birds representing 20 orders (Ali and Riply1983). Of these, only 25 species (2%) depredate on crops. Even though only a few of them have so far become serious pests of crops, their population levels are so high so as to cause considerable economic losses to the major crops grown in India. There is a tendency among the granivorous birds to form large flocks for feeding and most of the major pest species have a well-developed foraging behavior and a tendency to form large communal roosts. In the absence of natural wild food, these birds shift their feeding guild to the cultivated crops that are available to them in their habitat (Rao and Dubey 2006).

Birds are known to cause considerable economic damage to a variety of crops during vulnerable stages in different agro-ecological regions of the country. The extent of damage to any crop depends on several factors like concentration of local bird population, total area under the crop, cropping pattern, habitat of the area, season and physiological status of the birds. Crop losses due to the predator birds can either due to one species (parakeet) as in sunflower or a community of bird complex as in pearl millet, sorghum, paddy, groundnut and apple. Negative impact of birds on agricultural crops vary from region to region, season to season, depending on number of factors like number of depredatory species and their density, area under crop, ecology of the area, concentration of migrants, their food habits as well as the physical status of birds involved (AINPAO Tec. Bul. 8).

Assessment of losses due to birds to different crops viz., pearl millet, sorghum, maize, Paddy, wheat, sunflower, safflower, soybean, groundnut, oil palm, apple, kinnow, banana, date palm, pomegranate, guava, grapes, etc. was done in farmers' fields in Andhra Pradesh, Gujarat, Rajasthan, Delhi, Punjab, Kerala and Himachal Pradesh. Almost all cereals, pulses, oilseeds and several vegetable crops were susceptible to bird damage during sowing, seedling stage and ripening stage. Birds attacked the fruits at maturing or ripening stage. The cereals were more vulnerable to bird attack especially at the dough stage. Damage to the crops of smaller grains such as pearl millet and sorghum was more serious as compared to that in large size grains (e.g. maize). Small cereal grains were preferred by both smaller and larger birds, whereas, maize was depredated primarily by larger species such as parakeets and crows. Isolated fields were always prone to bird damage. Similarly, early or late maturing fields were highly susceptible to bird damage. Hence for the even distribution of bird damage, synchronization of crop cultivation is advocated.

Due to intensive farming, many species of birds obtain food from the agricultural fields and its vicinity throughout the year. Moreover, a few species viz., Rose ringed Parakeet (*Psittacula krameri*), House sparrow (*Passer domesticus*), weavers, munias and doves manage to nest in close proximity to agricultural fields. So, the congenial condition available to these species in recent times has led to their population build-up causing serious concerns amongst farmers and agricultural ornithologists (AINPAO Tec. Bul. 8).

Ecological aspects of pestline caused by birds to cereal crops have so far been studied only to a small extent by ornithologists in India. Whistler (1949), Dharamkumarsinhji (1956) and Ali (1971) mentioned House sparrow (Passer domesticus), baya, parakeet, peafowl, etc. as serious bird pests. Sharma (1972) gave an account of damage caused to crops by the peafowl. Fitzwater & Prakash (1973) concluded that the House sparrow and the baya as most serious bird pest to crops. Doves, House sparrow, White throated munia (*Lonchura malabarica*) and parakeet were the crop pests in the Indian desert (Rana, 1973).

An investigation on both basic and applied aspects of birds as harmful ecosystems has generated valid information that has helped to evolve technologies for their management for increasing crop production. A total of 63 species of birds belonging to 19 families have been identified to damaging several crops (Table 1). The number of bird species that affected various crops was: cereals-52, pulses-14, oilseeds-15 and fruits-23. Twenty-eight species of birds that inflicted damage to crops and fifteen of the beneficial species were omnivorous. Omnivorous birds have a dual role in our agro-ecosystem. The extent of damage in different stages of the crops by depredatory birds is given in Table 2.

DAMAGE CAUSED BY DEPREDATORY BIRDS TO VARIOUS CROPS

Pearl millet: A total of 24 depredatory species were recorded in pearl millet crop from five states. Rose-ringed Parakeet (*Psittacula krameri*) (Plate 1. a), Rosy Pastor (*Pastor roseus*), House sparrow (*Passer domesticus*) and Baya (*Ploceus philippinus*) were the predominant species that damaged the crop in Northwestern India. White eared Bulbul (*Pycnonotus leucotis*) was reported for the first time to feed on the crop in large numbers in the arid and semi-arid zones. Estimation of bird damage varied highly in different states. It was highest in Gujarat (0.3 to 40%) followed by Andhra Pradesh (1.5 to 9%), Punjab (45%) and Delhi (60%) during Kharif season. In Gujarat, bird damage to the summer crop was significantly less (0.2 to 2.1 %), due to the absence of migratory birds especially the Rosy Pastor, synchronization of crop cultivation also resulted in better yield compared to Kharif season (Table 2).

Wheat: Bird damage to wheat varied from 0.2 to 41 % in different parts of the country. The Damage was significantly high in Rajasthan as compared to that in Gujarat and Punjab. About 13 species of birds damaged standing wheat. Although, Rose-ringed Parakeet, Ring dove and Baya, were the most common species damaging the crop in most of the fields. Large flocks of Demoiselle Crane (*Anthropoides virgo*), Common Crane (*Grus grus*) and Short-toed Lark (*Calandrella brachydactyla*), heavily damaged wheat fields in Bhal area of Gujarat. Ruff (*Philomachus pugnax*) and Black winged godwit (*Limosa limosa*) are reported for the first time to damage wheat at sowing and seedling stages in the coastal areas of Gujarat (Table 2).

Paddy: Although the paddy is cultivated in several states of the country in vast areas, it was prone to heavy damage by birds under congenial ecological conditions. Damage to paddy was highest in Punjab (0.1 to 6.5 %), followed by Kerala (1.5 to 6%), Andhra Pradesh (l.5 to 3%) and Gujarat (0.1 to 1%). Thirty-nine species of birds fed on the grains of standing crop in Gujarat. Baya, House sparrow (*Passer domesticus*) and Rose-ringed Parakeet were common and predominant depredatory birds in most parts of the state. Gargany Teal (*Anas querquedula*) and Lesser Whistling Teal (*Dendrocygna javanica*) damaged paddy crop in Kole area of Kerala (Table 2).

Sorghum: Bird damage to sorghum was highest in Rajasthan (2.3 to 48%) as compared to that in Gujarat (0.4 to 18.6%) and Andhra Pradesh (0.5 to 16.6%). This is one of the most preferred crops by the granivorous birds like Rose-ringed Parakeet, Rosy Pastor and Bank Myna. Total 26 species were recorded feeding on sorghum (Plate 1. b and Table 2).

Maize: Bird damage to maize was relatively less in Gujarat (0.3 to 2.5%) as compared to Punjab (3.3 to 7.5%), Andhra Pradesh (3 to 9.1 %) and Rajasthan (0 to 20%). Ten species of birds were recorded to feed on maize, of which the Rose-ringed Parakeet was most important in all the states. In Andhra Pradesh, the bird damage in maize ranged between 10 to 40% and the damage was mainly caused by Rose-ringed Parakeet (Plate 1.c & Table 2).

Sunflower: Rose-ringed Parakeet and House crow (*Corvus splendens*) were the predominant depredators and caused 10 to 30 % damage in Andhra Pradesh and 40 to 90 % damage in Rajasthan. In Punjab the mean percentage of damage in different years of study ranged from 5.7 to 29 %. Only because of the bird problem, the crop could not be introduced in Gujarat state (Plate 2.a & Table 2).

Oil palm: The damage was higher both in south Gujarat (10 to 27%) and west Godavari district (3.3 to 30 %) of Andhra Pradesh. Common Crow (*Corvus splendens*), Jungle Crow (*Corvus macrorhynchos*), Rose-ringed Parakeet (*Psittacula krameri*) and Common myna (*Acridotheres tristis*) were the depredatory birds of this crop. For the first time, it was reported Pariah kite damage in oil palm gardens at NCZ of Andhra Pradesh to the tune of 30-50% (Plate 2. b & Table 2).

Groundnut: During sowing to sprouting stage, 3 to 33 % damage was done by ten species of birds in Saurashtra region of Gujarat. The migratory Demoiselle Cranes caused damage up to 10 % at the time of harvesting (Table 2).

Safflower: Rose-ringed Parakeet was the only species feeding mainly on the peripheral plants of the crop. The damage level was negligible in Andhra Pradesh and Gujarat (Plate 2.c & Table 2).

Apple: Apple orchards in Himachal Pradesh incurred 5 to 12.5 % loss due to bird damage. Although 11 species of birds fed on apple, Slatyheaded Parakeet and Rose-ringed Parakeet were the most important (Table 2).

Kinnow: Damage to kinnow fruits in Himachal Pradesh ranged from 3 to 16 % seven depredatory species was recorded, of which, Rose-ringed Parakeet and House crow caused maximum damage (Table 2).

Date palm: Date palm fruits were almost free from bird damage (0.1 to 1 %) in the Kachchh region of Gujarat. Although eight species of birds damaged the fruits, the Rose ringed Parakeet, House crow and Common myna were the major species of concern (Table 2).

Banana: Little Green Barbet, House crow and Jungle Crow damaged Banana crop in Kerala. Damage by different birds to the crops had been recorded viz., banana by small green barbet (*Magalaima viridis*) (21 %), rice by Baya weaver, parakeets and teals (9.1, 19.7 and 5.0% respectively), pulse by parakeets (15.6%) pepper by Koel, bulbul and barbets (15.9%), tomato by the House crow (up to 13.5%)Doves and Crows caused 25% damage in the sprouting cowpea and in seed bhendi by the parakeets (up to 11 %) in Kerala (Table 2).

Pomegranate: In Gujarat, bird damage was higher (3.6 to 20 %) as compared to Andhra Pradesh (3.6 to 5.5 %). Rose-ringed Parakeet was the common depredator in both the states. However, in Andhra Pradesh the House crow also damaged the fruits (Table 2).

Guava: Damage was moderate in Andhra Pradesh (1 to 4.5 %) and Punjab (2.5 to 5 %), but in Rajasthan it was high (4.5 to 24.5 %). Rose-ringed Parakeet was the common bird that damaged the fruits in all the three states.

House crow also caused significant damage in Andhra Pradesh and Rajasthan (Table 2).

Grape: Grape orchards of Ran gar eddy district of Andhra Pradesh suffered 2 to 27 % bird damage due to seven species. Rose ringed Parakeet, Rosy Pastor, Koel, sunbirds caused significant damage (Table 2).

Papaya: Koel, Brahminy Myna, Redvented bulbul, Jungle babbler (Turdoides striata) and Jungle crow damaged ripen fruits in Gujarat and Kerala (Table 2).

Pecan Nut: Rose-ringed Parakeet and Large Indian Parakeet caused severe damage to pecan nut (6 to 50 %) in Himachal Pradesh (Table 2).

Table.1. Important depredatory birds of Agricultural crops

Family and Species	**Crops**	**Damage Status**
Family: Threskiornithidae		
1. Black Ibis (*Pseudibis papillosa*)	C, OS	VL
Family: Anatidae		
2. Greylag Goose (*Anser anser*)	C, V	VL
3. Bar headed Goose (*A. indicus*)	C, V	VL
4. Lesser Whistling Teal (*Dendrocygna javanica*)	C, V	L
5. Ruddy Shelduck (*Tadorna ferruginea*)	C	L
6. Pintail (*Anas acuta*)	C	VL
7. Common Teal (*A. crecca*)	C	VL
8. Gargeny (*A. querquedula*)	C	VL
Family: Phasianidae		
9. Grey Partridge (*Francolinus pondicerianus*)	C, P, OS, W, F, V	H
10. Common Peafowl (*Pavo cristatus*)	C, P, OS, F, V	M
Family: Gruidae		
11. Common Crane (*Grus grus*)	C, P, OS, W, F, V	L
12. Sarus Crane (*G. antigone*)	C, OS,W	VL
13. Demoiselle Crane (*Anthropoides virgo*)	C,P,OS,W	VL
Family: Rallidae		
14. Purple Moorhen (*Porphyrio porphyrio*)	C,W,V	VL
Family: Charadriidae		
15. Blacktailed Godwit (*Limosa limosa*)	C	VL
16. Ruff and Reeve (*Philomachus pugnax*)	C	VL
Family: Columbidae		
17. Blue Rock Pigeon (*Columba livia*)	C,P,OS,W	H

18. Ring Dove (*Streptopelia decaocto*)	C,P,OS,W	M
19. Red Turtle Dove (*S. tranquebarica*)	C,P,OS,W	L
20. Spotted dove (*S. chinensis*)	C,P,OS,W	VL
21. Little Brown Dove (*S. senegalensis*)	C,P,OS,W	VL
Family: Psittacidae		
22. Large Indian Parakeet (*Psittacula eupatria*)	C,P,OS,W,F	VL
23. Roseringed Parakeet (*P. krameri*)	C,P,OS,W,F, V	H
24. Blossomheaded Parakeet (*P. cyanocephala*)	C,P,OS,F,V	VL
25. Slatyheaded Parakeet (*P. himalayana*)	F	VL
26. Bluewinged Parakeet (*P. columboides*)	F	VL
Family: Cuculidae		
27. Koel (Eudynamys scolopacea)	F,V	VL
Family: Capitonidae		
28. Great Hill Barbet (*Megalaima virens*)	F	VL
29. Small Green Barbet (*M. viridis*)	F,V	VL
Family: Picidae		
30. Scalybellied Green Woodpecker (*Picus squamatus*)	F	VL
31. Lesser Goldenbacked Woodpecker (*Dinopium bengalensis*)	F	VL
Family: Alaudidae		
32. Short-toed Lark (*Calandrella cinerea*)	C,W	VL
33. Skylark (*Alauda arvensis*)	C,W	VL
Family: Oriolidae		
34. Golden Oriole (*Oriolus oriolus*)	F	VL
35. Blackheaded Oriole (*O. xanthornus*)	F	VL
Family: Sturnidae		
36. Starling (*Sturnus vulgaris*)	C	VL
37. Rosy Pastor (*S. roseus*)	C,F	M
38. Common Myna (*Acridotheres tristis*)	C,F,V	M
39. Bank Myna (*A. ginginianus*)	C,F	VL
Family: Corvidae		
40. Redbilled Blue Magpie (*Cissa erythrorhyncha*)	F	VL
41. Indian Treepie (*Dendrocitta vagabunda*)	F	VL
42. House Crow (*Corvus splendens*)	C,P,OS,F,V	M
43. Jungle Crow (*C. macrohynchos*)	C,P,OS,F,V	VL
Family: Pycnonotidae		
44. Whitecheeked Bulbul (*Pycnonotus leucogenys*)	C,F	VL
45. Redvented Bulbul (*P. cafer*)	C,F	VL

Family: Muscicapidae		
46. Common Babbler (*Turdoides caudatus*)	C,W	VL
47. Large Grey Babbler (*T. malcolmi*)	C,W	VL
48. Jungle Babbler (*T. striatus*)	C,W	VL
49. Streaked Laughing thrush (*Garrulax lineatus*)	F	VL
Family: Nectainiidae		
50. Purple Sunbird (*Nectarinia asiatica*)	F	VL
Family: Ploceidae		
51. House Sparrow (*Passer domesticus*)	C,W,V	H
52. Yellowthroated Sparrow (*Petronia xanthocollis*)	C,W,V	M
53. Baya (*Ploceus philippinus*)	C,W	VL
54. Blackthroated Weaverbird (*P. benghalensis*)	C,W	VL
55. Streaked Weaverbird (*P. manyar*)	C,W	VL
56. Whitethroated Munia (*L. malabarica*)	C,W	VL
57. Whitebacked Munia (*L. striata*)	C,W	VL
58. Spotted Munia (*L. punctulata*)	C,W	VL
59. Blackheaded Munia (*L. malacca*)	C,W	VL
60. Black headed Bunting *(Emberiza melanocephala)*	C	VL
61. Redheded Bunting (*E. bruniceps*)	C	VL
62. Crested Bunting (*Melophus lathami*)	C	VL

Food: C: Cereals, P: Pulses, OS: Oilseeds, V: Vegetables, F: Fruits, W: Weeds; Damage status: VL: Very limited, L: Limited, M: Moderate, H: Heavily, *: Omnivorous

Source: Survey reports of coordinated centers of AINP on Agricultural Ornithology

Crops	**Stage of Crop**	**Extent of Damage**	**Bird Depredators**
Cereals			
Paddy (*Oryza sativa*)	Nursery	0.6-5%	Baya, House sparrow, White throated Munia, Spotted Munia, Blackheaded Munia, Blackthroated Weaver, Streaked Weaver, Purple Moorhen, Rock Pigeon, Ring Dove, Common Myna, House Crow.

	Ripening	1.4 - 22.9%	House sparrow, Baya, Black throated Weaver, Streaked Weaver, Whitethroated Munia, Spotted Munia, Blackheaded Munia, Roseringed Parakeet, Large Grey Babbler, Common Babbler, Jungle Babbler, Brahminy Duck, Lesser Whistling Teal, Gargany, Common Teal, Pintail, Purple Moorhen, Sarus Crane
Wheat (*Triticum aestivum*)	Sowing and seedling stage	0.5-6%	House Crow, Jungle Crow, Rock Pigeon, Ring Dove, Peafowl, Grey Partridge, Ruff, Blacktailed Godwit, Demoiselle Crane, Common Crane, Sarus Crane, Black Ibis
	Ripening stage	0.6-37%	House Sparrow, Roseringed Parakeet, Whitethorated Munia, Spotted Munia, Large Grey Babbler, Jungle Babbler, Indian Peafowl, Demoiselle Crane, Common Crane, Sarus Crane, Short- toed Lark, Rufous tailed Finch Lark, Blackheaded Bunting, Redheaded Bunting, Ring Dove
Maize (*Zea mays*)	Sowing and seedlings	10-20%	Rock Pigeon, Ring Dove, Spotted Dove, House Crow, Jungle Crow, Common Myna, Rose ringed Parakeet, Indian Peafowl, Grey Partridge.
	Ripening stage	6-39%	Roseringed Parakeet, House Crow, Large Indian Parakeet
Pearl Millet (*Pennisetum typhoideum*)	Sowing and seedling	0.5 - 6%	Rock Pigeon, Ring Dove, spotted Dove, Red Turtle Dove, Little Brown Dove, Baya, Blackthroated Weaver, Streaked Weaver, House Sparrow, Grey Partridge, Jungle Babbler, Large Grey Babbler
	Ripening	0.5 - 26%	House Sparrow, Baya, Black throated Weaver, streaked Weaver, Whitethroated Munia, Blackheaded Munia, Spotted Munia, Whitebacked Munia, Red Munia, Redheaded Bunting, Black headed Bunting,

			Common Myna, Redvented Bulbul, Whitecheeked Bulbul, Large Grey Babbler, Common Babbler, Jungle Babbler, Whiteheaded Babbler, Rosy Pastor, House Crow, Roseringed Parakeet, Ring Dove
Sorghum (*Sorghum vulgare*)	Sowing and seedling	0.5 - 8%	Rock Pigeon, Ring Dove, Spotted Dove, Little Brown Dove, Red Turtle Dove, Indian Peafowl, Grey artridge, Large Grey Babbler, Jungle Babbler, Common Babbler
	Ripening	0.7 - 44%	Roseringed Parakeet, House Sparrow, Baya, Black throated Weaver, Streaked Weaver, Whitethroated Munia, Spotted Munia, Whitebacked Munia, Black headed Munia, Rose Finch, Blackheaded Bunting, Redheaded Bunting, Ring Dove, Rosy Pastor, Common Myna, Bank Myna, House Crow, Jungle Crow, Blossomheaded Parakeet.
Pulses			
Black *gram* (*Vigna mungo*)	Sowing and seedling	0.2-3%	Rock Pigeon, Ring Dove, House Crow, Grey Partridge.
	Ripening	0.5-2.5%	Roseringed Parakeet, House Crow, Rock Pigeon, Ring Dove, Grey Partridge, Peafowl.
Green gram (*Phaseolus aureus*)	Sowing and seedling	0.3-3%	House Crow, Rock Pigeon, Ring Dove, Grey Partridge.
	Ripening	0.5-2%	Roseringed Parakeet, House Crow, Rock Pigeon, Ring Dove, Grey Partridge, Peafowl.
Chickpea (*Cicer arietinum*)	Sowing	0.5-3%	House Crow, Rock Pigeon, Ring Dove, Grey Partridge, Peafowl, Sarus Crane, Jungle Crow.
	Ripening	0.5-2%	Rock Pigeon, Ring Dove, Indian Peafowl, House Crow, Grey Partridge, Rose Ringed Parakeet.
Pigeon pea (*Cajanus*	Sowing and	0.2-2%	Rock Pigeon, Ring Dove, Indian Peafowl, House Crow, Jungle Crow,

cajan)	seedling		Grey Partridge
	Ripening	0.1-1%	Roseringed Parakeet, House Crow, Jungle Crow
Cowpea (*Vigna catjang*)	Sowing and seedling	0.5-3%	Rock Pigeon, Ring Dove, House Crow, Grey Partridge, Indian Peafowl
	Ripening	10-4-%	Roseringed Parakeet, Ring Dove, Rock Pigeon, Grey Partridge, Indian Peafowl, House Crow, Small Green Barbet
Oilseeds			
Sunflower (*Helianthus annuus*)	Sowing and seedling	0.5-3%	House Crow
	Ripening	10-40%	Roseringed Parakeet
Groundnut (*Arachis hypogaea*)	Sowing and seedling	0.5-36%	Rock Pigeon, Ring Dove, House Crow, Roseringed Parakeet, Indian Peafowl, Black Ibis
	Ripening	1-15%	House Crow, Jungle Crow, Demoiselle Crane, Common Crane, Sarus Crane, Black Ibis, Indian Peafowl
Safflower (*Carthamus tinctorius*)	Sowing	2-15%	House Crow
	Ripening		Roseringed Parakeet
Mustard (*Brassica nigra*)	Ripening		Roseringed Parakeet, Rock Pigeon, Ring Dove, Grey Babbler
Soyabean (*Glycine max-merr*)	Sowing and seedling	2-15%	Roseringed Parakeet, Rock Pigeon, Grey Partridge
	Ripening		Roseringed Parakeet, Indian Peafowl, Grey Partridge, Rock Pigeon
Oil Palm (*Elaels quineensis*)	Ripening	3-30%	Jungle Crow, House Crow, Indian Myna
Fruit crops			
Mango (*Mengifera indica*)	Ripening	3 -10%	Roseringed Parakeet

Guava (*Psidium guajava*)	Ripening	3-5%	Roseringed Parakeet, Large Indian Parakeet, Redvented Bulbul, House Crow, Jungle Crow, Small Green Barbet
Pomegranate (*Punica granatum*)	Ripening	2-20%	Roseringed Parakeet, Large Indian Parakeet, House Crow, Jungle Crow
Grape (*Vitis vinifera*)	Ripening	2-27%	Purple Sunbird, Redvented Bulbul, Roseringed Parakeet, Koel, Rosy Pastor, Common Myna, Golden Oriole
Date palm (*Phoenix dactylifera*)	Ripening	0.1-1%	Roseringed Parakeet, Bank Myna, Common Myna, Brahminy Myna, House Crow, Whitethroated Munia
Apple (*Malus Sylvestris*)	Ripening	5-13%	Slatyheaded Parakeet, Rose- ringed Parakeet, Large Indian Parakeet, Blossornheaded Parakeet, Himalayan Bulbul, Jungle Crow, Redbilled Blue Magpie, Great Hill Barbet, Whitecheeked Bulbul, Streaked Laughing Thrush, Scalybellied Green Woodpecker
Banana (*Musa paradisiaca*)	Ripening	19.4%	Small Green Barbet, House Crow, Jungle Crow, Common Myna
Kinnow (*Citrus aurantium*)	Ripening	3-16%	Roseringed Parakeet, Jungle Crow, Indian Treepie, Black headed Oriole, Small Green Barbet, Lesser Goldenbacked Woodpecker
Pecan nut	Ripening	6-50%	Roseringed Parakeet, Large Indian Parakeet
Papaya (*Carica papaya*)	Ripening		Koel, House Crow, Jungle Crow, Redvented Bulbul, Redvented Bulbul, Brahminy Myna, Small Green Barbet

Source: Survey reports of coordinated centers of AINP on Agricultural Ornithology

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PLATE 1

(a) Damage of Rose ringed Parakeet in Pearl millet

(b) Damage pattern of depredatory birds in Sorghum

(c) Damage of Rose ringed Parakeet in Maize

PLATE 2

(a)Damage of depredatory birds in Sunflower

(b)Damage of depredatory bird in Oil palm

(c) Damage of Rose ringed Parakeet in Safflower

RODENTS OF ECONOMIC IMPORTANCE IN AGRICULTURE AND STORAGE

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WHAT ARE RODENTS?

Rodents represent a highly diverse group under Order 'Rodentia' in Class Mammalia. They are one of the most successful animals on earth due to their vast breeding potential and adaptability to a variety of living conditions ranging from snowy heights of 5700 m to extremes of desert. The hairs on the body may be soft, spiny or in the form of quills. The tails are either naked or furry.

The thumbs are vestigial or absent. The sole of hind feet bears pads and toes vary from three to five. The digits of their limbs normally bear claws. The rodents use fore limbs for locomotion, climbing, digging, grooming, sexual grasping and manipulation of food. The fore feet / fore-paw has well developed four digits, 5th digit reduced. The hind limbs exclusively for locomotion. Hind foot with five digits and fleshy pads are longer in terrestrial and broader in arboreal rodent species. Rodents are characterized by a pair of chisel shaped incisors in each jaw, which have the power of persistent and are well adopted for gnawing. The incisor teeth grow @ 0.4 mm/day. In order to maintain the size of the incisors rodents nibble whatever hard substance they find in their habitat causing extensive damage to fields crops, stored grains and several other household articles. Correlated with the modification towards gnawing, the jaw muscles have become extremely powerful. Due to absence of canine teeth there is a wide gap between incisor and cheek teeth called as 'diastema'. The cheek teeth as a rule are adapted for dealing with vegetable food. Most of rodents have less than 22 teeth with one exception of Silvery mole rat with 28 teeth.

The dental formula is 1, 0, 0-2, 3
1, 0, 0-2, 3

Rodents are generally regarded as small mammals and most of them weigh around 150g. However, the largest rodent of the world, the Capybaras (*Hydrochoreus hydrochaeris*) weigh up to 60 kg and the smallest, the pygmy jerboa (*Salpingotus* sp) is hardly few grams and measures a couple of inches (excluding the tail). The Indian crested porcupine, *Hystrix indica* is regarded as the largest rodent in India. Rodents may have arboreal to subterranean/fossorial) life. The adult males can be identified by presence of testes in prominent scrotal sac. The genital papilla covers penis. The anus and genital papilla are distant, skin is thickly furred. In case of females the genital papilla (Non-functional penis) is present, which covers Clitoris. Anus and genital papilla are close together, skin is bare ore thinly furred.

RODENT DIVERSITY

Rodents represent almost 40% of all mammalian species in the world, whereas in India 26% of Indian mammalian species constituted rodent species. World over, the order Rodentia is represented by over 2200 living species under 481 genera in 33 families. Rodent diversity in India is relatively low represented by 103 species under 46 genera in three suborders viz., Sciuromorpha (13 genera and 27 species); Hystricomorpha (2 genera and 3 species) and Myomorpha (31 genera and 73 species). The suborders Sciuromorpha and Hystricomorpha are represented by one family each i.e., Sciuridae (squirrel family) and Hystricidae (porcupine family), respectively, whereas suborder Myomorpha is comprised of 5 families, viz., Dipodidae (birch mice); Platacanthamydae (dormice); Spalicidae/ Rhizomydae (bamboo rats); Cricetidae (hamsters) and Muridae (voles, rats, mice gerbils etc). Indian rodent fauna represents a mixture of Indian, Indochinese, Malayan, Ethiopian and Palaearctic elements.

RODENT MORPHOLOGY

- Externally the body is divided in three parts viz., head, body and tail with one pair of eyes, ears and two pairs of limbs (Fore and hind legs).
- Fur: Hair covering the entire body, except the nose; its main function is to maintain body temperature.
- Nose: Middle protuberance of the head with two orifices located above the mouth and having an olfactory and respiratory function.
- Vibrissae: Long tactile hair located around the nose and mouth used to detect obstacles during nocturnal forays.
- Pinna: External part of the ear made of cartilaginous lobes that capture sounds.
- Tail: Terminal appendage of the body covered with scales and containing blood vessels; it is used mainly for equilibrium.
- Claw: Somewhat curved, sharp pointy structure used especially for digging and defense.
- Digits: Terminal end of the limbs formed of various articulated bones bearing a claw and used mainly to feed and move about.
- Identification criteria: Morphological characters like, colour and texture of fur, body measurements (head body, ear, hind feet and tail length, size of tail in relation to head body length, and its hairiness, number and position of mammae, number of plantar pads, form and structure of teeth etc.

BREEDING AND OTHER BEHAVIORAL ATTRIBUTES

Most of the rodents of economic importance are fossorial in habit and make extensive burrows in the soil, except the squirrels, *Funambulus* sp. and a tree mouse, *Vandeleuria oleracea*, which are exclusively arboreal animals.

Most of the rodent pest species are nocturnal, except the squirrels and desert gerbil. The two commensal rodents viz., house rats and house mouse are basically nocturnal species but are also active in the day time.

As indicated earlier the success of rodents largely depends on their vast breeding potential coupled with enormous adaptive capabilities to survive in any conditions. Ideally, rodents breed round the year, however under field conditions, two major breeding peaks are observed which depends mainly upon availability of food. However, under commensal situations round the year breeding is noticed. The newly borne pups attain puberty within 6-16 weeks. They possess promiscuous breeding habits with 6-10 young ones in one litter. We have observed the highest litter sizes of 22 also. The breeding biology of a typical rodent as depicted in Table 1 clearly shows their huge breeding potential that makes them to maintain high population levels in any habitat.

Table 1. Breeding biology of pest rodents

Sl No	Attributes	Duration
1	Breeding season	Seasonal to Year-round
2	Age at puberty	6-16 weeks
3	Duration of heat	9-24 hours
4	Oestrous cycle	3-7 days
5	Mating habit	Promiscuous
6	Gestation period	18-30 days
7	Litter size	1-22
8	Post-partum heat	4-96 hours
9	Breeding potential	800-1200/ pair/year

Rodents, have adopted to thrive well under varied situations. They are omnivorous/cannibalistic and highly adaptive, mostly nocturnal and have well developed sense of smell, hear and touch. They are colour blind animals with wide range of vegetable food, however they may consume insects during periods of acute shortage of vegetal matter. At times they show cannibalistic behavior also. Some of the behavioual adaptations are presented in Table 2.

Table 2. Behavioral characteristics of Rodents

Traits	Characteristics
Sight	1.Colour blind, but can distinguish between shades
	2. Can discriminate between pattern and size and have good depth perception.
Taste	1.Wide food range
	2. Prefer fresh food but can thrive on garbage and decaying

	or spoiled food.
Hearing smell and touch	Well-developed senses; readily distinguish unusual noises and the long whiskers on their muzzle and guard hairs on the body serve as sensitive feelers
Balance	Excellent balancing sense enables them to run on pipes, narrow ledges or wires. Long tails act as balancing organ
Gnawing	Gnaw to gain entrance to food and to wear down their incisors to keep them in sharpened condition which grow @ 12 cm/year
Climbing and swimming	Can climb almost anything they can get their claws to hold. Roof rat is the better climber. Norway rats living in sewers are excellent swimmers.
Temperament	Bandicoots and Norway rats are much more aggressive than house rats and house mouse. Cannibalism is quite common.
Travel routes	Use fixed pathways, usually moves along the walls, under floors or through thick grass or litter.

RODENT SPECIES OF ECONOMIC IMPORTANCE

A pest is defined as "an animal that causes harm to humans, their crops, livestock or possessions". Organisms that inflict discomfort, annoyance, trouble and nuisance are also called pests. Of the 103 species of rodents belonging to 46 genera in India about a dozen qualify as pests, three to four may become occasional pests and some are localized pests. The main damage by rodents is to agricultural produce both in the field and in storage. They also cause damage to machinery, doors, windows, buildings, and roads by their gnawing activity. A large number of diseases including bubonic plague, leptospirosis, murine typhus etc are transmitted actively or passively i.e. as reservoirs or vectors by rodents. The pest species belong to only three families of order Rodentia, viz., hystricidae (porcupines), sciuridae (squirrels) and muridae (rats, mice gerbils etc). Most of the pest species belong to a single family muridae, however under family hystricidae only one species (Indian crested porcupine) and three sciurid fauna (Northern Palm squirrels, Southern Palm squirrel and Western ghat squirrel) are regarded as problem species. A brief account of rodent species of economic importance in agriculture and storage are discussed in following heads.

1. Family: Hystricidae (Porcupines)

The name porcupine is derived from Latin porcus meaning swine and French epine derived from Latin spina meaning thorns. It literally means 'the irritable back'. Porcupines are large bodied rodents with their body is covered with quills or spines. They are herbivorous although they eat meat also. The limbs are low, eyes small and ears short. Porcupines are able to make growling and snarling sounds. They have sharp sense of hearing and smell but sense of sight is poorly developed. From birth, the young ones able to feed on other food besides their mother's milk. The animals spend the day either in the burrows or in rock crevices. Three species of porcupines are known from India, they are the Asiatic brush-tailed Porcupine, Atherurus macrourus, Himalayan crestless Porcupine, Hystrix brachyuran and Indian crested Porcupine, Hystrix indica. The former two species are reported from NEH region of India, whereas the Indian crested porcupine occurs throughout India. Only Indian crested Porcupine, Hystrix indica.is regarded as a problem species in agriculture and forestry.

i) The Indian crested porcupine, Hystrix indica: The Indian crested Porcupine, Hystrix indica is the largest rodent species in India measuring 680-750 mm in length and weighing 11-18 kg. The neck and upper back are covered with distinct long, stiff, bristle-like hairs called quills (15-30 cm). The body is clothed with alternating dark brown and white quills and the tail is covered by short and broad quills. Short, coarse, black hairs thinly cover the ventral surface. It is widely distributed in India. The species is nocturnal and lives in caves, amongst rocks, or in burrows dug by them or by other animals. Porcupines breed throughout the year. Gestation lasts 109-112 days. Litter size ranges 1-8. They are known to be chiefly herbivorous feeding on succulent tubers, bulbs, roots, vegetables, ripe fruits and bark of trees. They show a definite preference for habitats near farms and croplands. They dig out burrows or stay in self-dry caves themselves. Porcupines also dwell in rock caves and crevices; in underground lodges dug by other mammals or under fallen trees. They may also dig their own dens in the soft floors of rain forests.

2. Family: Sciuridae (Squirrels and Marmots)

The squirrels are characterized by hairy body with thick tail covered with long hairs. There are 27 species in this family in India. They are commonly grouped as flying squirrels (11 species); Tree squirrels (14 species) and Marmots (2 species). As the name indicates the flying squirrels possess a broad parachute like flap (patagium) extending on either side of the body from wrist to knee that helps the animal in gliding. The tree squirrels are further grouped as giant squirrels (3 species) and medium sized squirrels (11 species). The tree squirrels are arboreal and diurnal in habit. All these tree squirrel species inhabit dense forests, except the two (Northern and the Southern Palm squirrels), which inhabits gardens, orchards, kitchen gardens, human habitations. The marmots, large sized animals (2 species) are found only at higher elevations in Leh Ladakh region. Of the 27 species in the family only three species are regarded as pests in agriculture. They are;

i) The Northern Palm or Five Stripped Squirrel, Funambulus pennanti: It is a medium sized rodent weighing 90g with a bushy tail. The dorsal side is greyish brown with five distinctly white stripes separated by four off white bands, hence the name five stripped squirrel. The species is distributed in

India, Pakistan, Nepal and parts of Iran. As the name indicate, the species in India occurs in Northern region from Rajasthan to West Bengal and in south up to northern district of Dharwad in Karnataka. It is also reported from Andaman Islands. The squirrel is diurnal and generally lives close to human habitation, orchards, gardens, parks and in areas with fairly good number of trees. Although reported to breed throughout the year, breeding is generally seasonal from March to September with peaks during March–April and July-September in Rajasthan. Gestation lasts for 40-42 days and litter size varies from 1-5. It is a serious problem in horticulture, kitchen gardens and forestry.

ii) The Southern Palm Squirrel, F. palmarum: This medium sized squirrel species also referred as three stripped squirrel has three white bands on the dorsal side separated by two off-white bands. It is mainly distributed in southern India. Its biology, habit and economic importance are similar to *F. pennant.*

iii) The Western Ghat Squirrel, F. tristriatus: It is the largest species of the genus Funumbulus weighing around 125g. The dorsal side has three narrow, white, or pale buff stripes separated by black or brown bands. The central stripe is thinner and shorter than the lateral ones. Belly is whitish with hair bases distinctly grey. This species inhabits a limited area of Western ghats. The species is arboreal and diurnal with peak activities in the morning and evenings. Feeding occurs at the same peaks. Breeding occurs throughout the year with peaks occurring from December to May (summer). The Western Ghat squirrel along inflicts immense losses to plantation crops especially cocoa in Kerala, Tamil Nadu and Karnataka.

3. Family: Muridae (Rats, Mice, Mole rats, Gerbils etc)

Muridae is the largest family of rodents with 56 species under 21 genera occurring in India. The list of pest rodents is also dominated by this family. The murids are small to medium sized rodents. They typically have slender bodies with scaled tails and pointed snouts with prominent whiskers, but with wide variation in these broad traits. Some murids have elongated legs and feet to allow them to move with a hopping motion, while others have broad feet and prehensile tails to improve their climbing ability. They are most commonly some shade of brown in colour, although many have black, grey, or white markings. They have excellent sense of smell hear and touch and live in wide variety of habitats from forests, crop lands, grasslands, mountain ranges, near human habitations and even in houses and godowns. They consume a wide range of foods depending upon the species. The family is further divided in two subfamilies Murinae (Rats, Mice, Mole rats etc) and Gerbillinae (gerbils). Major murid species of economic importance are:

A. Subfamily: Murinae: It is the largest subfamily represented by 52 species. The rodents of this group are commonly referred as rats, mole rats, mice, field mice, tree mice, metads etc. The tails are mostly ringed with small hairs. The rats and mice in general have tails longer than head body length whereas, tails of mole rats are shorter or equal to head body length. Following species are regarded as pests of crops and/ or storage.

i) The lesser bandicoot rat, Bandicota bengalensis: The species is robust with a round head and a broad muzzle weighing 200-350g. The body is covered with coarse fur which forms black-tipped piles on the dorsal side. The colour on the dorsal side is dark brown but may be blackish, pale brown or reddish. Tail is completely dark and paler below occasionally. Except the extreme arid tracts in western Rajasthan, *B. bengalensis* is widely distributed throughout India. It is a fossorial animal well adapted to various habitats and ecological conditions which include cultivated fields, pastures, forests, mountains, inter-tidal mangrove zones, semi-arid zones and also as a commensal in towns and cities across India. It also breeds throughout the year with a litter size ranges between 4-12. The lesser bandicoot is a serious pest of agriculture in India causing extensive damage to food and vegetable crops and coconut nurseries. The burrowing activity of lesser bandicoot rats causes damage to roots causing the slow death of trees/plants and irrigation channels. Besides it hoards large amount of food in its burrows.

ii) The larger bandicoot rat, Bandicota indica: It is the largest murid species of India, head and body normally ranging 200mm-366mm. Weight ranges from 500g to 2kg and more. Tail is shorter than head and body and is covered with hair throughout its length. The fur is very rough and quite long dorsally. The upper part of the body is dark or blackish brown and ventrum is grey, drab or dark. The larger bandicoot always lives close to human habitat but never inside the house or inside crop fields. It prefers habitat that has lot of garbage to feed and close to water bodies. In south India they are highly commensal. They prefer places close to human dwellings such as compounds, gardens, poultry and out houses. The species is nocturnal and fossorial. It makes burrows that may be simple consisting of an unbranched tunnels. Burrow openings are recognized by the presence of wet globules of fresh earth and soft faecal matter.

iii) The soft furred field rat, Millardia meltada: The species also referred as metad is distributed throughout India, except the north eastern hill regions. Body colour light to dark grey dorsally with foot and belly being off white. The animals weigh between 40-70 g. It is one of the most predominant rodent pests in almost all the states inhabiting crop fields and grasslands usually choosing the drier patches. It is a nocturnal animal and makes simple burrows. In Rajasthan metads breed throughout the year with peak reproduction occurring spring and monsoon season.

iv) Indian field mouse, Mus booduga: This tiny mouse is distributed all over India including Andaman and Nicobar Islands and Leh Ladakh. The mouse weighs between 10-15g. Colour of dorsum varies from dark brown to lighter sandy brown with under parts whitish to slightly grey. This nocturnal and fossorial mouse makes simple burrows at 50-60 cm depth with characteristic scooped soil near openings. Peak breeding is noticed during September October and February to June with a litter size of 6-13.

v) The house rat, Rattus rattus: It is a medium sized rat weighing 150-200g. It is also called as roof rat, black rat, and ship rat and is the most abundant and widely distributed rodent species in India as well as the world. It is characterized by long tail, slender body and pointed snout. The dorsal fur is mostly blackish in commensal forms which range to yellow to brown black with pale white belly in wild forms. It is nocturnal and colonial and lives in houses, godowns, stores, poultry farms, crop fields, adjacent to villages. House rats breed throughout the year, reportedly with two peaks of reproduction viz. March-April and August-September with a litter size of 1-9.

vi) House mouse, Mus musculus: A widely distributed species, the house is very small rodent weighing 15-20 g. The tail is naked and longer than the head-body length. It is nocturnal in habit nesting in rafts, crevices in walls, amidst staked undisturbed bags of food grains in godowns, table drawers, often lives in fields by digging burrows. The mouse breeds round the year with a litter size of 1-8. In fields it is known to damage sugarcane, groundnut etc.

vii) Wroghton's rat, R. rattus wroughtoni: It is a subspecies of *Rattus rattus* with characteristic white belly. It weighs around 95 g and abundantly found in southern India from the semi evergreen forests, scrub jungles, teak plantations of Karnataka, throughout the state of Kerala in houses, coconut palms and tree cavities and is a serious pest of coconut, areca nut and cocoa plantations. It is an arboreal rodent spending more than 80% of time on tree tops. It lives in nests constructed in tree holes and either in the interspace of nuts or inside stipules in the spindle portion of coconut.

viii) Short tailed mole rat, Nesokia indica: The species is relatively large weighing around 200g. The heavily built body is dull to brown on the dorsum and has a lighter ventral side. Tail is shorter than head body length. Fur is short and rough. In India it is distributed mainly in Punjab, Rajasthan, Haryana, Uttar Pradesh, Himachal Pradesh and Union Territory of Delhi. The rat is nocturnal and fossorial and prefers bunds in cultivated fields along water channels but also occurs in natural vegetation and garden lawns. Nocturnal and fossorial. It burrows preferably at higher levels and the burrow opening have characteristic heap of dug soil at the burrow entrance. It breeds during winters with a litter size of 2-6.

B. Sub family: Gerbillinae (Gerbils): Gerbils have long tails longer than head body length and possess tuft of hair at the tail tip. Four gerbil species occur in India, viz., Indian hairy footed gerbil, *Gerbillus gleadowi*; Baluchisatan gerbil, *G. nanus*; Indian desert gerbil, *Meriones hurrianae* and Indian gerbil, *Tatera indica*. The former two species (Gerbillus) occasionally attain pest status in rain fed crops grown on sand dunes or inter-dunal spaces in arid regions. Of the latter two gerbil species, which are serious pests, *Meriones hurrianae* is a regional pest causing immense losses to crops, grasses and forestry plantations in arid regions, whereas *T. indica* is an important rodent pest throughout India.

i) Indian gerbil, Tatera indica: It is a medium sized rodent weighing about 100-150g. The tail is longer than head-body length and possesses tuft of hair at the tip (characteristic of all gerbils). Generally light brown in colour, varying from sandy brown to red on the dorsal side and pure to off white ventrally. The range of distribution of *T. indica* extends westwards to Iran, Syria, Turkey, Iraq, Arabia, Afghanistan, Pakistan and southwards to Sri Lanka. However, in India the species is ubiquitous occurring throughout except the hills. The species inhabits open plains, loose sandy soils of the desert, and is usually found at the edges of cultivation. Burrows are dug near hedges, thickets or under bushes, sometimes inside the field. The gerbils are nocturnal and their food consists of grain, roots, leaves and grass. It breeds throughout the year in arid Rajasthan with maximum littering (1-9) in the month of August and a minor peak in February. *T. indica* is a serious pest of all crops and is regarded as reservoir of plague bacteria.

ii) Indian desert gerbil, Meriones hurrianae: In India, the desert gerbils are restricted to Northwest desert of Rajasthan adjoining Haryana, North West Gujarat and Punjab. The adult weighs 40-160 g., colour is sandy grey to brownish grey dorsally and white to off-white ventrally. Tail is pale with black or dark brown tussle of hair at the tip. The gerbils prefer sandy habitat most followed the ruderal habitat of arid zones. Burrows can be found not only near cultivation but far away in waste lands, thorny forests and open desert. Desert gerbils are diurnal and live in smaller colonies. They breed throughout the year with two peaks during February and July -November with a litter size of 1-9. It is regarded as a common pest of bajra, wheat, chillies, vegetable crops, grass and other vegetation in arid regions.

CHANGING SCENARIO OF RODENT PEST SPECIES

In India the land use pattern is being drastically modified with new crops for increased food productivity and economic sustainability. Canalization of river waters and utilization of ground water is being done for increasing the irrigated areas. Due to such developments many mono cropped (rainfed) areas are being converted in double/triple cropped areas. Many high value crops are replacing traditional crops resulting in altered land use pattern in most of the agro ecological regions of the Country. These changes along with large scale urbanization activities during last 3-4 decades is also transforming the natural habitats of native rodents.

Most of the rodent pests are primarily herbivores and fossorial in habit therefore their associations are largely influenced by vegetation and soil types of the habitat, which influences their relative abundance and species composition. It has been found that two truly xeric rodent fauna, viz., *M. hurrianae* and *Gerbillus gleadowi* occurring exclusively in arid regions prefer highly drained sandy soils with vegetation and are well adapted to desertic conditions, whereas *T. indica* and *Golunda ellioti* prefer medium textured soils with some moisture and *B. bengalensis* and *Nesokia indica* prefer clayey-loam with fair amount of soil moisture. Thus, habitat use for rodent species especially in agro-ecosystems may be linked to land use patterns. Seasonal changes in food supply may cause movements of animals between refuse habitats and impact habitats (crops). Accordingly, some species have acclimatized in certain cropping systems/regions. The impact of changing land use pattern on rodent pests can be well understood by specific examples in some regions.

During the last over 100-150 years the entire Indus Basin covering the states of Punjab, Haryana and northern Rajasthan have witnessed great ecological transformation from dry deciduous scrub grassland to irrigated cropland mainly due to canalization of river waters for irrigation. The phenomenon of ecological transformation of rodent communities can be well explained on existing scenario of Punjab and northern Rajasthan which are under irrigation since more than 70-100 years. The information available from Punjab indicated that during nineteen seventies eight murids, all having oriental affinities (except *T. indica*) were categorized as common and abundant species, whereas the mole rats, viz., *B. bengalensis* and *N. indica* were rare. By early nineties the scenario has further changed and *B. bengalensis* represented 10% of total murid fauna in Punjab. Presently *B. bengalensis* has occupied the predominant position followed by *Mus* spp *M. meltada* and *T. indica*. Thus, intensively irrigated cropped areas in the region indicated shift in rodent faunal diversity. In northern Rajasthan, the irrigated croplands in Sri Ganganagar district represents a type of transitional zone for such transformation. During early 1970s *T. indica* (44.7%) was predominant followed by *M. meltada* (21.1%) and *M. hurrianae* (15.8%) and grouped them under the category of abundant species in Sri Ganganagar District. *M. musculus* and *N. indica* with 7.9% occurrence each were referred as common and *F. pennanti* (2.6%) as rare. The other true xeric elements like *G. gleadowi* and *G. nanus* were not observed at all. Our studies in this district revealed that *M. hurrianae*, another xeric species has been further driven away from irrigated crop fields to sandier and drier areas. Even large populations of *M. musculus* were noticed in sugarcane and cotton fields in Sri Ganganagar. *N. indica* and *B. bengalensis*, true mesic species were found in irrigated croplands and fruit orchards. It showed that within a short span of 60-65 years, the desert elements (*Gerbillus* and *Meriones*) have been replaced by sub mesic forms (*M. meltada*) to mesic mole rats (bandicoots) in irrigated croplands of Sri Ganganagar and Bikaner district.

Changes in rodent species composition have been observed in urban areas also. During early years of last century *B. bengalensis* was predominant (60%) followed by *R. rattus* (14%) and *R. norvrgicus* (20%) in Kolkata, however within 60 years share of bandicoots reached to 91%, practically replacing *R. rattus* (0.3%) and *R. norvegicus* (7.1%). Similar shift in rodent species composition was reported from Mumbai also where *R. rattus* was predominant (> 90%) with B. bengalensis representing only 1% in 1907 but now it is just reverse. These replacements are mainly due to faster expansion of cities towards open fields and more aggressive and colonial behaviour of lesser bandicoots. These bandicoots known to be a mesic rodent has shown its presence in desert by establishing its population in Jodhpur city also during last 10-15 years. Spread of bandicoots, across the country is a matter of serious concern as it is not only finding new areas, but also replacing the native fauna, thereby threatening the rodent diversity. Besides, the economic consequences due to increasing population of bandicoots are manifold. These bandicoots being heavy bodied animals have higher damaging potential as it requires more than two times food daily in comparison to medium/ small sized native rodents. The bandicoots are aggressive burrowers and hoards the food inside the burrows.

CONCLUSION

Generally, a rodent pest complex of 3-4 species occurs in any particular agro-climatic region. *B. bengalensis* is the most predominant rodent pest species and is well distributed in crop fields and residential areas all over the country, except the extreme hot arid regions. Other species of national importance in the crop fields are *M. meltada*, *T. indica* and *M. booduga*. Some rodent species are having pest status restricted to a particular region. For example, Indian desert gerbil, *M. hurrianae* is pests in rain-fed crops in arid areas. Similarly, in South India *Rattus rattus wroughtoni* is a major problem in plantation crops. In Islands *Rattus rattus* are the major problem. Among squirrels, *F. pennanti* infest fruit orchard in North India and *F. tristriatus* is a pest of fruits and plantation crops in South India. Indian crested porcupine, *Hystrix indica* with pan India distribution is regarded as pest of tuber crops. Another species, *Nesokia indica*, primarily a north Indian element is considered as pest of irrigated crops, fruit orchards and forestry plantation.

The two most common commensal rodents, viz., *R. rattus* and *M. musculus* are major problem species in indoors like houses, godown etc but in recent years they have shown atavism in their habitat by making their presence felt in crop fields also in different regions.

INTEGRATED BIRD MANAGEMENT METHODS IN REDUCING CROP DAMAGE IN AGRICULTURAL AND HORTICULTURAL CROPS

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INTRODUCTION

Agricultural production in India is mainly affected by insect pests, plant diseases and weed plants to a greater extent. In the recent times, avian fauna and mammalian fauna with special reference to rodents, wild boars, blue bull and monkeys started gaining pest status and in certain cases a huge damage is being encountered due to some of these vertebrate pests. Among them, depredatory birds have become regular menace for farmers in major crops resulting into enormous damage. Over exploitation of forest resources by the mankind forced birds are out of their natural habitat and compelled them to depend on cultivated crops such as Rice, Maize, Sorghum, Pulses, Oil seeds, Fruits & Vegetables. Depredatory birds in general moves in flocks/groups and their activity is more during early morning and evening hours.

However, today in our country, views of the administrators and agricultural research scientists towards the depredatory birds have certainly changed. Attitude of the farmers towards birds is changing at slower rate but they are still tolerant as they are under the influence of religious preaching. Under present economical crisis and modernization of agricultural ecosystem, there is a need to manage all the pests, including birds and higher vertebrates for sustainable productivity.

The following are some of the traditional methods in genera used by the farming community across the country in different crops. The effectiveness of these methods is not validated, but to some extent these methods help in reducing bird damage.

TRADITIONAL METHODS

'Machan': A machan is erected amidst the maize crop. A semicircular mat made of bamboo splits is puton the machan to prepare a small hut for the shelter which is locally called dhagla. Sometimes, instead of semicircular mat, an umbrella type structure made of leaves of Butea monosperma and bamboo sticks (locally called dengcha) is placed on machan. Loud calls are made from the machan to keep away the birds. Stones are thrown by locally made equipment called gophana (sling) to drive away birds (Plate 1.a).

Flagged bamboos and flagged leader shoots: Pieces of plastics and coloured clothes are tied on bamboo sticks which are erected amidst the crop in the field to keep away the birds. Sometimes these are placed at the periphery only. When the crop reaches the milky stage, flags of cloth are tied on leader shoots of some of the tall trees.

Use of 'Owl-rests':

Cushion owl-rests: A coiled mass of Tectona grandis leaves is wrapped at one end of a bamboo stick. Dozens of such sticks are erected in the field keeping the leaf mass upward. At night, owls are attracted to these perches and prey on night dwelling rats (Fig. 2). This method is generally used in fields of wheat and gram.

Pole owl-rests: Poles of bamboo culms, 0.5 to 1.5 m long, are erected amidst gram, wheat and barley crops to provide perching stations to the owlets during night.

Pitcher-effigy (scare crows): Pitcher-effigies (locally called byawana or taoon) are prepared by the farmers with locally available material. An old pitcher (terracotta vessel), having black outer surface due to use in kitchen for cooking purpose, is kept upside down on a vertically erected wooden pole of a man's height to symbolize the head of a man having black hair. Sometimes head is made by black cloth also. Then, a horizontal stick is tied to the vertical pole to resemble arms raised to shoulder level. An old shirt (kurta) is put on the wooden structure to make an effigy of a man working in field (Plate 1.b). These effigies are said to be effective in repelling raiding birds from crops (Sharma 1994).

Hanging Crows: A hung dead crow is said to be very effective in repelling crows. This method is equally effective in houses as well as in fields.

Calls made by 'ghunku':'Ghunku' is a simple device made by locally available material. An earthen pitcher used in persian wheel (to draw water from wells, locally called ged) is taken and a piece of goat skin having a hole in its centre is tied to the mouth of the pitcher. A tall feather of peacock is inserted in the hole and a knot is made at its lower end. This apparatus is held between the feet and then a massage like action is made on the feather with the thumb and the first finger. To make the action easy, few oil drops are also applied on the feather. A loud call is generated by this apparatus which is said to be effective in frightening nocturnal animals. This is also used during day-time to keep away birds.

Halan: This method is mainly practised by Saharias. A string is tied loosely around or across the fields. Leaves of Tectona grandis are tied to the string in a series. This festoon of leaves is connected by another string at the mid-point. A man sitting on a machan pulls the string in jerky motions and dry, hanging leaves produce a typical buzz like sound which keeps away the birds and other animals. This indigenous device is called halan (i.e., something which moves). Many variations of this system can be seen in the state.

Sometimes bells instead of leaves are also used. Sometimes, single leaf halan (locally called jalra) made by bamboo pole and striated Tectona grandis leaf are also erected amidst the crop to keep away rodents and birds.

Drum beating: Drums are beaten from some elevated places or machans to keep away the flocks of grain eating birds. This method is said to be effective against the raid of locusts also.

Use of feathery grass inflorescence: Just after sowing of wheat and gram, feathery inflorescence of Saccharum bengalense are erected at random in the fields. This method is said to be effective to keep away the grain eating birds. This method is mainly practiced in eastern Rajasthan.

Use of white-washed stones: In southern Rajasthan, white-washed stones are put in a series at the periphery of gram and wheat fields to keep away the Sarus Cranes, Grey Partridges, Hares, etc.

Methods to protect harvested crop: Generally, the harvested stems of jowar and bajra are bundled and then piled in a conical shaped heap, keeping all the ear ends upwards. These conical heaps are locally called chhaurs. Spiny bushes of Zizyphus nummularia are cut and placed on the top of the heap to keep away the bird flocks. This method is much practiced in eastern and central Rajasthan (Sharma 1991).

ECO-FRIENDLY BOTANICAL AND MECHANICAL METHODS FOR MANAGEMENT OF DEPREDATORY BIRDS

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As a part of All India Net Work Project on Vertebrate Pest Management, multi-location trials for evaluation of different ecofriendly management practices were carried out to determine their efficacy, feasibility and economic viability under different agro climatic zones. These methods were tested all over India, i.e., Himachal Pradesh in the north to Kerala in the south with the varying cropping patterns stretched in different climatic regimes. As a result, several ecofriendly economical management practices have been evolved for minimizing losses caused by depredatory birds which are elucidated as under:

WRAPPING METHOD ON MAIZE CROP

Covering maize cobs by wrapping adjacent green leaves around them reduced the damage to a negligible level by parakeets and crows, which were the major problem birds. Being hidden camouflaged, the wrapped cobs escape detection by birds and thus the crop is protected (Plate 1.c). It is a very simple and effective method, which does not involve any material cost and is les laborious than scaring. This method does not have negative impact on the grain yield. All cobs need not be covered. Since parakeet damage is restricted to peripheral rows, covering 0f 50% cobs at random on outer 3 rows of the field are sufficient to effectively reduce bird damage.

REFLECTIVE RIBBON FOR BIRD SCARING

Reflective ribbon is a polyester film with a shining metallic coating with red on one side and silver on the other. It is prepared by cutting along continuous polyester sheet in to strips of 1.5 cm width. Such strips, preferably 15 to 20 m long, are fixed parallel to the crop at 0.5 m height above the crop and at 5 m intervals using bamboo poles and strings. For better reflection, the ribbon should be fixed in north to south direction. During sunshine the reflection of sunlight and humming noise produced by the wind scares the birds from the field (Plate 2.a). The device is effective only for 15-20 days. After that the birds gets used to it. The ribbons do not scare birds under poor light condition and when the crop is grown in isolation. The technique of bird scaring by ribbons is very effective and easily acceptable to the farmers. Birds like rose ringed parakeet, House crow (*Corvus splendens*) and mynas on the crops like sunflower, maize, sorghum, pearl millet and orchards are scared by this devise. The reflective tapes have been proved to be effective against the Demoiselle cranes in groundnut and against depredatory birds in other cereals and fruit crops.

SCREEN CROP

Thick planting of sorghum (fodder) as well as of maize fodder significantly reduced parakeet damage in maize crop grown for grain production. Besides giving better yield, this practice also provided additional fodder.

BIO-ACOUSTICS

The acoustic equipment can also effectively drive birds away. It consists of 1 stereo tape recorder with 30 w amplifier, 2 speakers and one 12 v battery. Pre-recorded tapes of distress calls of birds are played. The operation of the equipment should be done from a distance of about 100 meters and the speakers should be kept in bushy spots near the field area. Depending on the intensity of bird activity, the frequency of play should be setup at regular time intervals. Broadcasting of such distress calls of depredatory birds keeps the birds away from maize fields and also other crops (Plate 3a).

AUTOMATIC MECHANICAL BIRD SCARER OR PYROTECHNIC METHOD

Automatic bird scarer can also be employed. This is a sound producing device which works continuously for a whole day with 1 kg of calcium carbide and water. One-hectare areas can be covered with this method and it is found effective in reducing crop losses by birds. Care must be taken about the frequency of firing and change of positions and directions to avoid bird getting habituated (Plate 3 b).

BOTANICAL REPELLENTS

Neem cake solution is prepared by soaking neem cake @ 200 or 300 g/lt of water and kept for fermentation for 8 - 10 days. The fermented solution is than decanted and this solution is used as spray fluid. Neem cake solution @ 200 g for liter of water showed effective in controlling bird damage in Maize. Spraying of botanical formulation like BBR+ and Fortune Azar (Neem formulation) in the field, reduced number of visiting birds, in Andhra Pradesh. Spraying of BBR+ (5%) and Fortune Azar (5%) in the fields of pearl millet reduced bird visits and significantly (68%) reduced bird damage in Gujarat. Tobacco leaf decoction (10%) spray on sorghum at milk stage reduced bird damage at Anand, Gujarat. In Punjab, bird damage to sunflower on block area showed lesser damage. A minimum block size 21 acres is required to reduce parakeet damage to 1 % level.

SEED TREATMENT FOR PROTECTING SPROUTING SEEDS

Thiram 0.5% and Copper-oxychloride is very effective in reducing the seedling losses due to birds in maize, chickpea soyabean, sunflower and groundnut. However, it is yet to be investigated whether the reduction in early seedling vigour by thiram treatment has any significant effect on the crop yield.

HABITAT MANIPULATION

Creating continuous disturbances to the nesting sites of the depredatory breeding birds in and around the cropped areas that will force the birds to leave breeding grounds and shift to another area. For parakeets in addition to manual destruction of nests, closing the entrance of the nests proved effective reducing their population. Planting of some fruit bearing trees like Manila tamarind (*Pithecolobium dulce*), Flame of the forest (*Butea monosperma*) Mulberry (*Morus alba*) and Toothbrush Tree (*Salvadora persica*) in and around cropped areas attract many granivorous birds during fruiting period and reduces the impact at vulnerable stage of the crop (maize) (Plate 3c).

SPRAYING OF EGG SOLUTION

Spraying of egg solution@ 25 ml/lt of water was very effective in control of bird damage in Safflower, Maize, Sunflower, Sorghum, Bajra, and other food crops. This method is effective for 10 days; second spray is recommended if damage is seen after 10 days. Application of this innovative method the yields of different crops increased from 30-69%. (Plate 2.b).

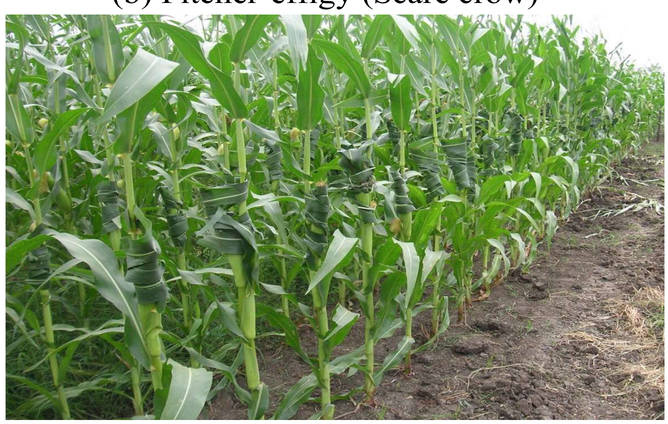
REFLECTIVE PAPER PLATE

This method is very effective during the milky stage of the crop. In this, the paper plates are arranged on the stalk behind the flower such that the reflective surface faces outside. So that the sun rays will be reflected back, this prevents the birds' vision and approaching the crop. Birds may approach the crop, in case of the absence of sunlight may not find suitable perch on the flower due to slippery surface. Hence this is a cost affective method in minimizing the crop loss (Plate 2.c).

PLATE 1

(a) Using of Machan to scaring the depredatory birds

(b) Pitcher-effigy (Scare crow)



(c) Wrapping in maize

PLATE 2

(a) Reflective ribbons on maize crop

(b) Spraying of egg solution on Sorghum

(c) Reflective paper plates around the Sunflower stalks

PLATE 3

(a) Bioacoustics – a potential bird scaring device

(b) Automatic mechanical bird scarer or pyrotechnic method

(c) Habitat manipulation practices to reduce depredatory bird damage

RODENT MANAGEMENT IN FIELD CROPS

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INTRODUCTION

Rodents form a very diverse group of mammals comprising of porcupines, squirrels, rats, gerbils, mice, mole rats etc. Out of over 2000 species only a limited number of them are regarded as pests in agriculture. For example, in Australia and Western Europe only 4 out of 67 species and 5 out of 61 species have been reported to cause damage to agriculture respectively. India, being a highly diverse country, this number is more as about a dozen species are regarded as pests of agriculture and storage. Most of the pest species belong to family muridae, but even in this group only a few species fall in the category of 'pests'. Estimates of rodent damage to crops vary immensely depending upon the species, crop stage, agro-ecological region, availability of food and physical environment. Management of rodent pests is a very intricate as well as a ticklish problem. Unlike insects, rodents are very secretive and not easily observed because many of them are nocturnal. They infest an area throughout the year as compared to insects which may appear sporadically only for short periods in certain seasons. Often, the farmers must rely on various signs like damaged plants, tooth marks, burrows and traps to identify them. Moreover, the rodents are highly mobile and a single individual may typically cause damage to several plants in one night by residing at some other place.

AGRO-ECOSYSTEMS THE MOST PREFERRED RODENT HABITAT

Generally, crop fields are homogeneous and manmade ecosystem with a plant community dominated by one or two crop species. Depending upon the availability of water, climate suitability and the soil fertility, different crops are grown in an area, which regularly supply energy rich food to rodents in a limited area. The availability of food and cover to native rodents are continuous with different crops grown in different seasons. The rodent species that can take advantage of the temporarily abundant food and at the same time somehow overcome the periods when the conditions are poor, make rodents' a good candidate as agricultural pests. Thus, agricultural fields serve as a highly productive rodent habitat. Among various crops, sugarcane, rice, wheat, groundnut and fodder crop fields serve as an ideal habitat for rodent pests in India. Similarly threshing yards located near crop fields too act as an excellent abode for food and shelter of rodents.

MAJOR RODENT PEST SPECIES

As mentioned above, about a dozen rodent species are regarded as pest in agriculture, however a pest complex of 2-4 species occurs in any particular agro-climatic region (Table1). The lesser bandicoot rat, *Bandicota bengalensis* is the most predominant rodent pest species and is well distributed in crop fields and residential areas all over the country. The species once not known from arid regions is now showing its presence in the Indian desert regions also by establishing their population in urban locales of Bikaner and Jodhpur. Other species of national importance in the fields are soft furred field rat, *Millardia meltada*, Indian gerbil, *Tatera indica* and little Indian field mice, *Mus booduga*. In arid areas of western Rajasthan, Indian desert gerbil, *Meriones hurrianae* and Hairy footed gerbil, *Gerbillus gleadowi* have attained pest status in rain-fed crops. Another species, Short tailed mole rat, *Nesokia indica* has also been listed as pest of irrigated crops, fruit orchards and forestry plantation in northern India. Among squirrel fauna, the five stripped squirrel, *Funambulus pennanti* in north India and three stripped squirrel, *F. palmarum* in south India causes extensive damage to fruit and vegetable crops in nurseries and fields/orchards in north India. Another squiirel species, western ghat squirrel, *F. tristriatusis* regarded as pest of plantation crops, especially cocoa in south India. Likewise, the Indian crested porcupine, *Hystrix indica* is regarded as pest of tuber crops.

Table 1. Distribution of rodent pests in different cropping systems

(a) Dryland/rainfed crops		
(i) Arid zone	:	*M. hurrianae-G. gleadow- T. indica.*
(ii) Semi arid tracts (North Zone)	:	*T. indica-M. meltada.*
(iii) Semi arid tracts (South Zone)	:	*T. indica-M. meltada-B. bengalensis*
(b) Irrigated crops		
Arid and Semi arid tracts (North Zone)	:	*T. indica-M. melatada-M. hurrianae.*
Semi arid tracts (South Zone)	:	*B. bengalensis-M. meltada.*
(iii) Deep water rice	:	*B. bengalensis-Mus spp.*
(c) Plantation crops		
(i) Coconut-cocoa-are canut	:	*R.r. wroughtoni-F. palmarum-F. tristriatus*
(ii) Sugarcane	:	*B. bengalensis-M. meltada-Mus spp.*
(iii) Spices	:	*F. palmarum-F. tristriatus.*
Stores/godowns	.1	*R. rattus -M. musculus-B. bengalensis*

A sub species of house rat commonly referred as Wroughton's rat, *Rattus rattus wroughtoni* is a serious rodent pest in plantation crops viz., coconut, coca, areca nut etc. The two most common commensal rodents, viz., the house rat, *Rattus rattus* and house mouse, Mus musculus are a serious problem in houses, godowms and storage. However, in recent years even these two species are showing their presence in crop fields also.

RODENT CONTROL TECHNIQUES

1. Cultural control: This technique is primarily based on ecological concepts wherein the rodents' habitat is manipulated in such a way that creates stress for native rodent pests. In fact, rodents prefer to a habitat where it gets food and hiding places. The crop refuge of earlier crops, weedy fields and high bunds provide a highly conducive environment to rodents o thrive well near or in the crop fields. The methods involving habitat manipulations are low cost treatments with little modification in crop husbandry practices. For example, deep ploughing helps in destruction of rodent burrows that encourages out migration of native rodents. Likewise, removal of wild vegetation and refuge of previous crops and reduction in bund size etc also helps in migration of pest rodents from crop fields. Moreover, the habitat stress created by these practices enhances the chances of rodents falling prey to predators.

2. Employment of rat catchers: Certain tribal communities in India viz., Mushars and Nats (Bihar); Yenadis (Andhra Pradesh), Irulas and Kuruwas (Tamil Nadu) and many communities in Northeastern hill states consume rodents. Farmers of Andhra Pradesh and Tamil Nadu employ such tribals for physical elimination of field rodents. This practice is often done at crop maturity stage when the rodent's destruction is at its peak, however this eco-friendly method may prove effective if performed in a planned schedule.

3. Mechanical control: Mechanical removal of rodent population from any habitat is mainly done by use of different types of traps. This method is in vogue all over the world, but its success in field rodent control is quite limited. Trapping is a very effective method on threshing floors and indoor habitats. However, under fields situations this method may be used as a follow up measure after bringing down the rodent pest population by poison baiting. Trapping provides, the information on species composition and density of pest population, hence can be successfully used as a diagnostic tool for survey and monitoring purpose. The traps may be of single (Sherman/Snap traps) or multiple catch (Wonder traps) type. In snap traps the rodents are killed whereas others catch live rodents. Introduction of natural glues or sticky traps have opened new avenues in the rodent control in stores, godowns and houses. Rodents use visual and olfactory cues towards traps, therefore camouflaging the traps with bushes, grasses etc. in fields enhances the trap success considerably. Indigenous Tanjore kitty traps in South India and bamboo snap traps in Jhoom fields of NEH region have proved quite effective.

4. Biological control: Use of disease-causing microbes has very little scope for rodent control particularly due to inherent possibility of spread of the diseases to man and livestock. WHO committee on Zoonosis has also doubted the practical application of microbial rodenticides due to possible public health hazards. However, predators may exert some predatory pressure on rodent pests. Several vertebrates, mainly birds and mammals are listed as natural predators of rodents in literature. However, cats in domestic situation and snakes, owls, mongoose and varanids in fields are predominant predators of rodents. Information on stomach contents and feacal matters of predators indicated that rodents constitute over 75% diet of snakes viz., Cobra and Russel viper and 61% of spotted owlet. Introduction and rehabilitation of barn owls, *Tyto alba* in oil palm plantation of Malaysia was reported to reduce the rodent damage to oil palm from 19.4% to 1.4% within two years. Barn owls and fields rodents both are nocturnal and barn owls being an excellent hunter's rodents easily fall prey to the owls. In the Cauvery Delta of Tamil Nadu, studies on barn owl as potential bio control agent of bandicoots revealed a predation rate of 1-6 (Av 1.58) rodents/night. *B. bengalensis* (40%) and *M. musculus* (33%) constituted the major prey items of barn owls. Scientists of the Project have developed nest boxes for barn owls, which can be established in the fields. Likewise, in the endemic areas of barn owls even erection of T-shape perches for barn owls have proved effective in reducing rodent populations in Tamil Nadu.

Success rate of biological control of rodents through other predators is not very encouraging because rodents do not constitute the sole diet of most predators and exert relatively lower predatory pressure as compared to faster turnover of rodents. For example, snakes in captivity require only one rodent in three days indicating a very poor potential.

5. Trap Barrier System (TBS): It is a type of physical control of field rodents by putting fences around crops, especially rice. The techniques involve use of plastic fence around the main crop and keeping multiple catch traps near the holes made in the fences protects the crop from rodents. This system described as eco-friendly was named as Trap barrier system (TBS). In later years it was improved by limiting the fencing around trap crop sown before the main crop. The trap crop lures the rodents from the surrounding areas and rodents get trapped in large numbers. The TBS+ trap crop provides a halo of protection to neighboring rice crops. The system broadly referred as ecologically sound rodent management technology when applied on community basis (Community trap barrier system or CTBS) and has proved cost effective in some south Asian countries for rice rat management. In India, studies on TBS in rice in Andhra Pradesh initiated recently have shown encouraging results, but further researches are needed on this aspect under Indian conditions.

6. Chemical Control: Use of rodenticides is most common, expedient and humane method to control pest rodents. They have greater scope in large-scale control operations, since mixed population of several species are encountered in fields. Zinc phosphide, a broad-spectrum rodenticide is most widely used rodent poison in India. It is recommended at 2-2.5% concentration in cereal baits. It yields around 60-70% control success with single application. It is highly toxic to non-target species. Besides major limitation in its frequent use is development of bait shyness/poison aversion in the target species after sub-lethal consumption. Bait shyness may persist for more than 1-3 months in different rodent species. Its bait can be prepared by mixing the the chemical powder (2-2.5% w/w basis) in oil smeared cereals viz., wheat, jowar, pearl millet etc. Because of high toxicity, zinc phosphide is recommended for field rodents only, where the rodent infestation is very high. For controlling the residual rodents (surviving after zinc phosphide treatment), another rodenticide viz., aluminium phosphide (a fumigant) or second-generation anticoagulant rodenticide has been advocated.

Among second generation anticoagulants several products viz., bromadiolone, brodifacoum, flocoumafen and difethialone have shown their potency against Indian rodent species (Table 2), of these only bromadiolone (0.005%) is registered with Central Insecticide Board for rodent control in fields and also in commensal situations. The other anticoagulant rodenticide registered in India is coumatetralyl, is recommended to be used in cereal mixed baits at 0.0375%, but is currently not available. The second-generation anticoagulants are effective as single dose rodenticide and have very potent antidote in vitamin K1. Moreover, they are highly effective at a very small concentration in baits (0.005%), thus are considered relatively safer to non-targets. They can be used for rodent management not only in fields but under commensal situations also.

Table 2. Single dose toxicity of grain baits of second-generation anticoagulant rodenticides

Rodent species	Per cent mortality and (mean days to death) with			
	Bromadiolone (0.005%)	**Brodifacoum (0.005%)**	**Flocoumafen (0.005%)**	**Difethialone (0.0025%)**
B. bengalensis	100	100 (6.6)	100	100 (5.8)
T. indica	100 (9.5)	90 (6.9)	90 (8.2)	100 (7.9)
R. meltada	100 (6.4)	80-100 (6.6-7.1)	100 (5.7)	100
M. hurrinae	88	83-100 (4.7-8.0)	100 (7.0)	100 (5.9)
R. rattus	100 (7.5)	83-100 (8.0-10.8)	100 (8.6))	100 (5.9)
M. musculus	91 (8.1)	60-100 (4.6-8.4)	100 (6.8)	-
M. booduga	83	83 (9.4)	-	-
F. pennanti	-	66 (7.0)	100 (8.1)	100 (6.1)

INTEGRATED RODENT PEST MANAGEMENT (IRPM)

Simply knowing the enemy and the control methods does not qualify for effective management of rodents. Though several methods of rodent control have been discussed in preceding pages, but no single method can prove its worth if applied in isolation. Since rodents are highly evolved mammals and its long association with the wisest mammal i.e. man, has made them wiser than man by learning various tactics to avoid many harmful activities performed by man against them. Trap avoidance, bait shyness/aversion to acute poisons, resistance/cross resistance to anticoagulants are only few examples of rodent's behavior, which very often questions the man's endeavors for their control. Therefore, an IPM approach based on sound eco-biology and ethology of pest species vis-à-vis population reduction technologies having economic viability and sociological acceptance needs to be evolved. Thus, IPM is a bio-ecological system and is therefore dynamic one. Following components of population regulation require special mention for devising an IPRM system in different agro-ecosystems.

1. Population ecology: Rodents are prolific breeders with a litter size of up to 20 young ones per female (Table 2). Such a high fecundity of rodents is countered by several biotic and abiotic factors operating in nature. Rodents sometimes regulate their own population by feeding on their own young-ones (cannibalism) during any type of stress depending upon the carrying capacity of their habitat. In drought years the rodent population maintains a low profile due to scarcity of natural food, however the population explodes in a good rainfall year succeeding any drought year. Most of the rodent's species exhibit relatively lower population levels during winters and summers. Maximum pest population is encountered in monsoon and post monsoon seasons. However, *B. bengalensis* was reported to show very fast population growth rate from 108/ha in November to 446/ha even in December during winters in West Bengal. Such population upsurges are results of favourable climatic condition along with food availability leading to intensive breeding and immigration. A perusal of data on peak breeding season of Indian rodents (Table 3) indicates a bimodal breeding pattern, which coincides with the maturity/harvesting stage of field crops. Seasonal movements of B. bengalensis have also been reported where the bandicoot migrates from rice to sugarcane to wheat fields after their harvest period. Bunds or fields with more weeds are an ideal place for burrowing rodents. Similarly, denser fields with more crop density afford both cover and energy required for reproductive activity of field rodents. Mobility on the pest forms a limited social structure based on hierarchy. The members live in small territories called "home range" which depends on position of food reserves and cover condition and presence of other species.

Table 3. Peak breeding season and litter size of important rodent species

Rodent species	Peak breeding season	Litter size
G. gleadowi	May, June and October to January	2-5 (summer)
		5-6 (winter)
T. indica	Monsoon (in arid regions)	1-9
	Oct-Nov (in Karnataka)	1-12
M. hurrianae	(i) February to March	1-9
	(ii) July and September to November	2-7
R. rattus	April-September	1-9
M. meltada	Spring and Monsoon (in Rajasthan)	3-9
	March-May and July-Oct. (in Punjab)	-
M. musculus	All the year round	1-8
M. booduga	(i) September-October	-
	(ii)February and June	6-13
N. indica	January-March and August-October	2-5
B. bengalensis	All the year round	4-12

2. Pest behaviour: Most of the field rodents are fossorial and nocturnal, which protect them from direct attack of predators and climatic vagaries. The burrows could be very simple (*T. indica, M. booduga* and *M. meltada*) or complicated (*B. bengalensis* and *M. hurrianae*). The mole rats (*B. bengalensis* and *N. indica*) keep their burrow openings tightly plugged with soil for safety against natural enemies and flooding. Food and feeding behaviour of rodents indicate their preference for various food items, which helps in selecting an effective carrier for poison bait preparation. Studies on bait preferences have revealed that almost many of the pest rodent species prefer wheat, rice and pearl millet with slight variation. Similarly, preference for oils, sugar, salts etc. have helped in selection of bait additives. Based on the preference of rodents, poison bait recommended by AINP is pearl millet/wheat with groundnut oil in Rajasthan and Gujarat, wheat+sugar+mustard oil in Northern India, rice/ragi with coconut oil in Southern India. Even the effect of bait shyness induced by sub-lethal intake of acute poisons can be mitigated to some extent by changing the base and oil component of the baits.

3. Damage threshold levels: Under IPM, pest population is to be manipulated to maintain them below economic threshold levels. Limited studies have been made in India in this respect. For working out these levels, rodent pest population needs to be regularly monitored in order to decide any management action. This may be done either on burrow count basis or actual damage done by pests. Live burrow counts are very convenient and useful index for rodent population in crop fields. Generally, a live burrow density upto 25 per hectare can be regarded as low, 25-50 as medium and more than 50 as severe pest intensity for deciding management plans for pest rodents.

4. Ecological take over: The crop fields are mostly inhabited by a complex of 2-4 rodent species, however any one of them may be predominant. It has been generally observed that when any control operation is undertaken the predominant species experiences the first knockdown. Later in the absence of the dominant species, the co-dominants or subdominants take over the dominant status and multiplies un-checked in the absence of any competition. Secondly, the immigration of new rodents from neighborhood is also very fast. For example, sustained trapping or poison baiting which may bring down the pest population to the extent of 80-90%, often fails to maintain this success any longer due to large scale immigration from surrounding untreated areas. Our experience in the arid regions indicated that after discontinuation of control operation after 3 crop seasons, the rodent pest population is restored to its original level with in few days.

PLANNING FOR CHEMICAL CONTROL

Rodent pest management is mainly depending on the use of rodenticides. Timing of control and placement of poison baits plays significant role in yielding desired results. Large scale rodenticidal baiting in a campaign is generally advocated, because summers being lean period, rodent species maintains lower population with majority consisting of adults. More over due to shortage of green food in summers the acceptance of bait is also increased. The adoption of the technology by farming community is also quite encouraging as they are relatively free during this period and can freely do the job on cooperative basis. Similarly, second operation could be undertaken before sowing of rabi crops.

1. Bait Preparations: It is an important aspect of rodenticide application technique, which is often overlooked. The proportion of toxicant to bait should be maintained properly. Too heavy dosages may repel the pest and with too light dosages rodents may stop eating before consuming the lethal dose resulting into development of bait shyness. It is, therefore, important that the toxicant is uniformly distributed through the bait mixture rather than left as distasteful clumps. Since most of the rodneticides are available in powder from, the oil component of the bait is equally important. The technique of bait preparation is as follows:

i) Zinc phosphide (2.0%): Being an acute rodenticide zinc phosphide baiting cannot be resorted very frequently as it induces bait shyness/ poison aversion among the survivors who had consumed sub lethal doses. Therefore, efforts should be made to cover maximum possible area in one go so that majority of population consumes lethal doses through poison baits. Therefore, besides selecting most preferred cereal bait, it is mandatory to go for pre- baiting (baits without poison). Pre baiting acclimatizes the field rodents for new food material, thus when poison baiting is done after 2-3 days of pre baiting, the native rodents consume the poison bait in sufficient quantities leading to effective kill to the tune of 60-70%. The baiting technology requires only three components i.e., cereal, edible oil and zinc phosphide. For preparing pre bait material any cereal (wheat, rice, ragi, jowar, pearl millet etc) is smeared with edible oil (mustard, ground nut, sesame, coconut oil) @ 2% w/w basis. This oil smeared cereal is called as pre bait material. Similarly, for preparing poison baits the zinc phosphide powder (2% w/w/basis) is thoroughly mixed with the oil smeared cereal.

ii) Bromadiolone (0.005%): Bromadiolone is an anticoagulant rodenticide with chronic action on target animals, therefore there is no need for pre-baiting while using this rodenticide bait. This rodenticide bait is available in two forms (i) ready to use wax block baits with recommended concentrations of 0.005%) and (ii) as Bromadiolone Concentrate Bait (CB) at 0.25% a.i. and farmers are required to prepare baits for application. Its bait can be prepared by mixing CB powder with any cereal grain (wheat, rice, ragi, jowar, pearl millet etc) smeared with edible oil (mustard, ground nut, sesame, coconut oil @ 2% n w/w basis). Thus, for preparing one kg of bromadiolone bait of recommended dosage (0.005%), we need 960g cereal; 20g oil and 20g bromadolone CB powder.

2. Bait Application: Two methods of bait placement is recommended for fields i.e. burrow baiting and use of bait stations. The former method provides better opportunity to access fresh baits by target rodents and protects the non-targets from its exposure. Similarly, bait station made of locally available materials viz., bamboo or PVC pipes have also proved highly effective. The bait stations should be placed on the runways aligning vertical surfaces like bunds for better success.

i) Burrow baiting: In this method the baits are applied deep in the live rodent burrows. For identifying live rodent burrows, all the existing burrow openings should invariably be plugged in the evening and the re-opened next morning are referred as live / active burrows, which are to be treated with pre/poison baits. While using zinc phosphide, small amount of pre-bait (10-15 g per burrow) is inserted deep in the burrows in largest possible area. After 2-3 days of pre-baiting, zinc phosphide bait is rolled deep inside the live burrows @ 10 g per burrow. At the end of treatment, the unconsumed poison bait and dead rodents should be collected and buried deep. Likewise, poison baits of bromadiolone may also be used in the burrows @ 10g/live burrow (without pre baiting). Baiting in live burrows not only enhances the efficacy but economizes the poison bait material, labour cost and time. To assess the control success the burrows are plugged again after 3-4 days of treatment (with zinc phosphide) or 10-15 days after bromadiolone baiting and reopened burrows are examined on the next day. Based on the pre and post treatment live burrows per cent control success can be worked out.

ii) Use of bait stations: Several types of indigenous bait containers have been used in India for keeping the baits. The basic idea of selecting bait containers is that the bait should be easily accessible to the target species and should reduce the hazard to non targets. This will also protect the baits from rain and other weathering. Indigenously, procured items like mud channels, hollow bamboo pieces, broken pitchers, coconut shells etc. have been effectively utilized for this purpose.

iii) Burrow fumigation: Aluminium phosphide, a burrow fumigant is available in 12 g tablet form. For fumigation, all the existing burrow openings are plugged with wet mud and with the help of applicator, one tablet of 12 g aluminium phosphide/ burrow is inserted in the active burrows, which should also be plugged with mud to check the escape of lethal gas.

RECOMMENDATIONS FOR RODENT MANAGEMENT IN MAJOR CROPS

1. Rice

- Summer plough & reduced bund sizes.
- Timely field operations pudding and transplantation and avoid staggered planting.
- Allow alleyways in transplanted rice 20 cm for every 2 meters crop.
- During the first month of transplanting. Poison baiting in bait stations @ 5-10 bait stations/ha. Place bait material twice in a week (50 g/bait station).
- Place bromadiolone bait (15 g/ burrow) inside the burrows.
- At grain formation stage kill burrow dwelling rats by natural smoke employing burrow fumigator

2. Ground nut

- Removal of weeds and crop refuge and trimming of bunds
- Baiting with bromadiolone (0.005%) at Flowering stage and ii. At pod maturity stage OR
- ii. Baiting with zinc phosphide (2.0%) at Flowering stage and ii. bromadiolone (0.005%) at pod maturity stage OR
- Baiting with bromadiolone (0.005%) at germination stage and ii. At pod formation stage OR
- Baiting with zinc phosphide (2.0%) at germination stage and ii. bromadiolone (0.005%) at pod formation stage.

3. Wheat

- Removal of weeds and crop refuge and trimming of bunds
- Bromadiolone (0.005%) baiting at tillering Stage followed by Bromadiolone (0.005%) at milky stage of crop @ 10 g poison bait/burrow OR
- ii. Baiting with zinc phosphide (2.0%) at tillering stage and ii. bromadiolone (0.005%) at milky stage @ 10 g poison bait/burrow.
- In Wheat crop grown under rice and maize residue management in Punjab double burrow baiting (with zinc phosphide (2%) followed by bromadiolone (0.005%) baiting after sowing (November-December) and baiting with bromadiolone (0.005%) before grain maturity stage (February-March).

4. Sugarcane

- Removal of weeds and crop refuge and trimming of bunds
- Two rodenticidal treatments viz., (i) in July (after rice transplantation) and (ii) in October-November (after rice harvest). At each of these two timings poison baiting with zinc phosphide (2%) or bromadiolone (0.005%) may be adopted followed by another baiting after 15 days with bromadiolone (0.005%). A third rodenticidal baiting is also recommended during with bromadiolone @800g/acre in January if the harvest of crop is delayed after January-February.

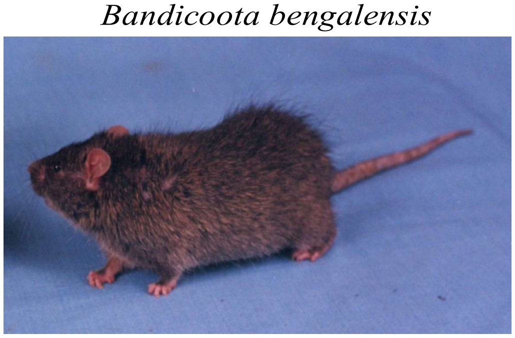
5. Plantation crops

- Coconut: (i) Trunk banding (ii) Baiting with bromadiolone (0.005%) 100g/ five crowns at an alternate picking and baiting with bromadiolone (0.005%) @ 10g/burrow
- Cocoa: (i) Place of 4-5 bromadiolone cakes (0.005%) / tree at the base and on the forks of pod bearing branches and (ii) Initiate rodent control operation before ripening of the cocoa pods and repeat at weekly intervals. And (iii) Bromadiolone cakes should also be kept in the fields in bait stations.

- Oil palm: (i) Place bromadiolone cakes at the base of each young palm. For mature palms place one bromadiolone cake along the rodent's pathway at the base of the palm and on the crown. Treat rodent harbourage also to check reinfestation.

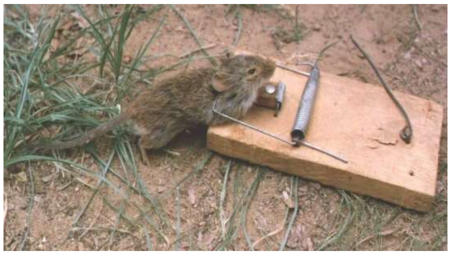
Needless to mention, the common propriety resources like Government lands viz., rail/road side land, panchayat land, forests etc. are the real breeding shelters and act as focal centers for their further advances towards crop fields. Since these do not belong to any individuals, the rodent control work, especially during summer months must be taken up by farmers in such areas also.

Common rodent pest species

Tatera indica 	*Meriones hurrinae* 
Mellardia meltada 	*Nesokia indica* 
Bandicoota bengalensis 	*Funambulus pennanti* 

Types of rodent traps

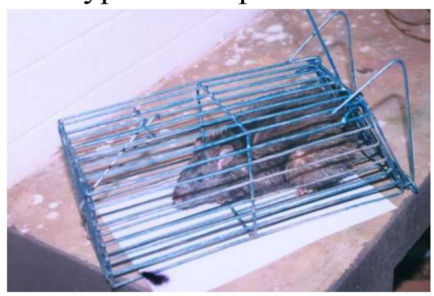
Snap traps (kill type)



Butta Traps

Bamboo tarps (NEH)

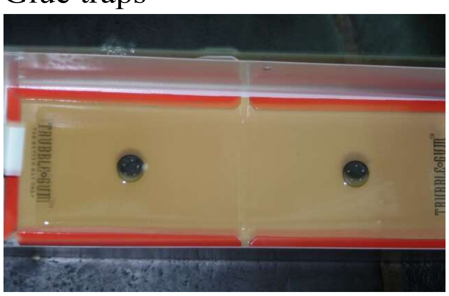
Box type live traps



Sherman Live traps

Wonder multi catch trap

Glue traps



UTILISATION OF SOLAR ENERGY FOR MANAGING HIGHER VERTEBRATES

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INTRODUCTION

In order to keep pace with the development there is rise in energy use but it has adverse effects on greenhouse gas emissions on climate due to burning of fast depleting fossil fuels. In this context, we need to harness and use more and more renewable forms of energy, especially solar energy that is plentiful on most part of the country. Also, at several locations harnessing wind power and utilizing biomass could be effective alternatives. Solar based devices may also work in an integrated manner with small wind turbines as hybrid devices. At present, about 13% of the country's installed electricity generation capacity is contributed by renewable sources e.g. wind, solar, bioenergy, hydro etc., which is about 33,791 MW as on 1-1-2015. In agricultural sector, energy is directly used for pumping irrigation water, operating different mechanized farm implements/tools and processing of foods. Share of agricultural sector in total energy consumption is about 7-8% and further increase in energy use from its present value of 1.6 kW ha-1 to 2.5 kW ha-1 is expected to meet the production target of next 20 years.

AVAILABILITY OF SOLAR IRRADIANCE IN INDIA

The arid and semi-arid part of the country receives much more radiation as compared to the rest of the country. The average irradiance on horizontal surface in India is 5.6 kWh m-2 day-1 and at Jodhpur 6.11 kWh m-2 day-1. The solar resource map of India shows that western India receives maximum amount of solar irradiation whereas major portion of India (~140 million ha) is receiving solar irradiation of 5-5.5 kWh m-2 day-1 (Fig. 1). The solar resource map along with grid wise solar radiation data can also be downloaded from http://mnre.gov.in/sec/solar-assmnt.htm. The cold arid region of the country located at Leh and Ladakh receives highest amount of radiation, which is about 7-7.5 kWh m-2 day-1. At Jodhpur, maximum amount of radiation is received during the month of April (7.17 kWh m-2 day-1), whereas the minimum amount of radiation is received during the month of December (5.12 kWh m-2 day-1). In total, 6390 kWh of solar energy is available during a year at Jodhpur. Moreover, most of the days in a year at Jodhpur are cloud free which has been measured and reported in several literatures as 300 days clear sunny days in a year. Available solar irradiation and utilizable energy for any location in India can also be viewed from http://pvwatts.nrel.gov/ or http://mnre.gov.in/sec/solar-assmnt.htm.

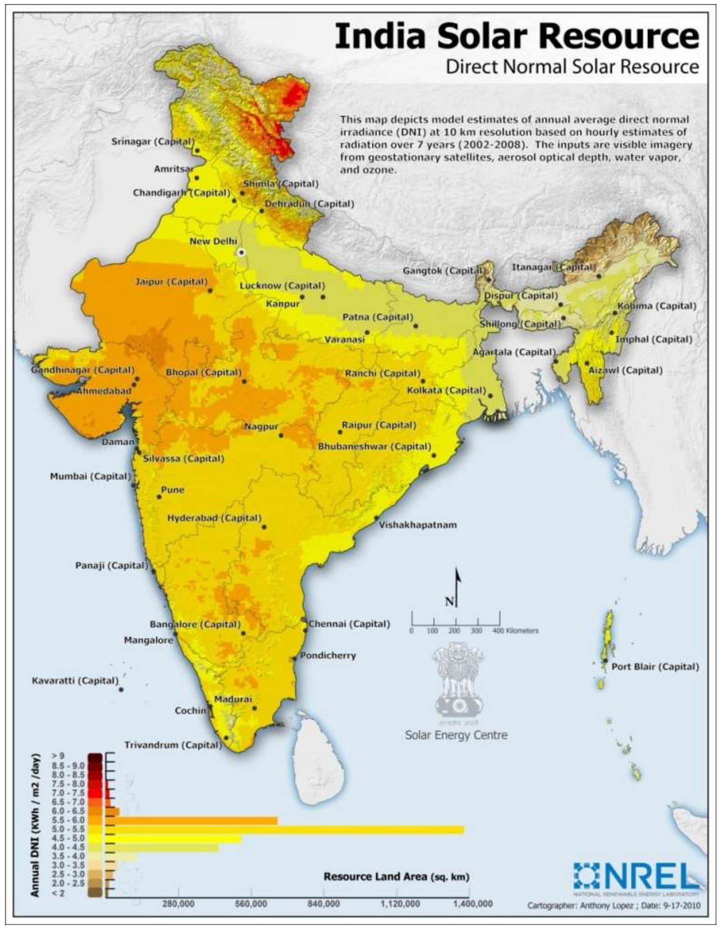

Fig. 1: Solar resource map of India

RENEWABLE ENERGY SCENARIOS IN WORLD VIS-A-VIS INDIA

At present, renewable energy share to world's global electricity production is about 22.8% (by the end of 2014), out of which 16.6% is contributed by hydropower, 3.1% by wind energy, 1.8% by biomass-power and 0.9% by solar PV (Renewable Energy Network for 21st Century, REN21). Cumulative renewable installed capacity in the world is 1712 GW including hydropower installation of 1055 GW. Annual growth rate of cumulative renewable energy installed capacity in 2014 was about 8%, whereas the annual capacity addition grew by 24% in 2014 as compared to 2013. India ranks 7th in the world in total renewable energy installed capacity while China tops the list followed by USA and Germany. In China, wind energy and hydropower installations are the major contributors to renewables whereas in USA, geothermal energy and in Germany, solar PV is the dominant contributor. India ranks 5th in the world in total wind energy installation after China, USA, Germany and Spain, whereas it is 10th in world among solar PV installation. Globally, 15% of the world population has no access of electricity. India today is home to one-sixth of the world's population, but accounts for only 6% of global energy use and one in five of the population – 240 million people – still lacks access to electricity (World energy council, 2015). Therefore, much effort is needed in India to fulfill the future energy demand and specifically through renewable energy sources.

At present about 13% of energy generation in India is met through renewable sources e.g. wind, solar, biomass etc. whereas coal is till the main source contributing about 60% of total generation. During last few years, a great stride has been made to install solar PV plants, wind turbine, hydropower, biogass e.g. renewable installed cumulative capacity has been increased from 24914 MW in 2011-12 to 42752.21 by the end of 2015-16 with an annual growth rate of 17.8% (Fig. 2).

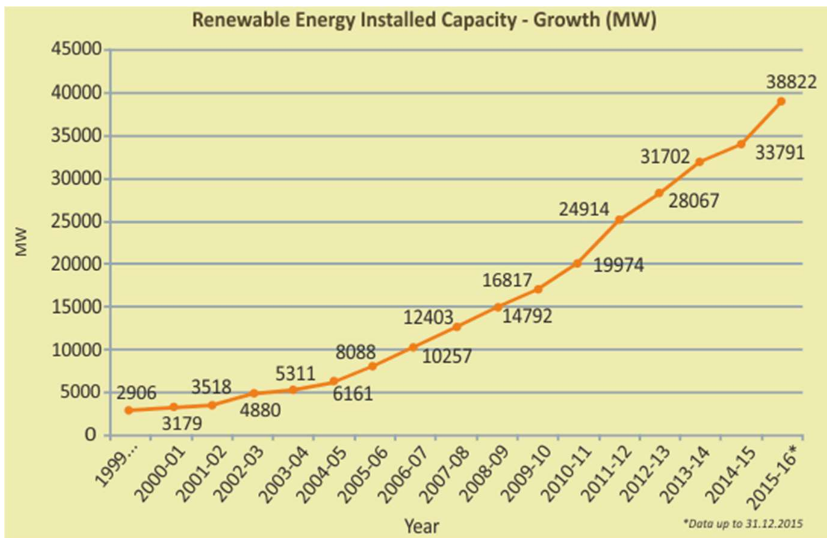

Fig. 2: Renewable energy installation capacity in India

By the end of March 2016, wind energy installation shares the maximum 26769.05 MW (62%) whereas solar PV installation shares 6762.85 MW (15.8%). Rajasthan and Gujarat share ~58% of the total solar power installed capacity in the country, whereas these two states share 29.2% of total wind installed capacity. Tamilnadu and Maharastra dominate the total wind installation in our country by sharing 52% of total installed capacity by the end of 2014-15. Simultaneously 60,000 MW of wind energy is targeted to achieve by 2022. Among these national targets, Rajasthan and Gujarat shares the maximum (8600 and 8800 MW, respectively).

NATIONAL SOLAR MISSION

The National Solar Mission (NSM) has been in operation since 2010 with the following targets in three phases (Table 1). The target has been revised in 2015 to a total grid connected solar power generation of 1,00,000 MW comprising 40,000 MW roof top generation and 60,000 MW grid connected solar power plants (Resolution of MNRE, Govt of India, No. 30/80/2014-15/NSM dated 1st July 2015).

Table 1: National solar mission targets

Sr. No.	Application segment	Target for Phase I (2010-13)	Target for Phase II (2013-17)	Target for Phase III (2017-22)
1.	Grid connected solar power generation	1,100 MW	4,000 MW	1,00,000 MW*
2.	Off-grid solar applications (includes solar PV pump)	200 MW	1,000 MW	2,000 MW
3.	Solar thermal collectors	7 million sq. m.	15 million sq. m.	20 million sq. m.
4.	Solar lighting systems	5 million	10 million	20 million

*The revised target (Source: Ministry of Renewable Energy Sources, Govt. of India)

In Rajasthan several initiatives have been taken to support the growth targets of renewable energy in India by Rajasthan Renewable Energy Corporation Limited (RRECL) (www.rrecl.com). Total wind energy installed capacity in Rajasthan up to March 2016 is 4006.845 MW whereas total grid connected solar PV installed capacity is 1259.35 MW (as on 31st November, 2015). Solar power park has been developed at Badhla, Phalodi with an area of 1360 ha and expected generation capacity of about 600-700 MW. MoU has been signed between RRECL and Suzlon to develop solar wind hybrid project of 1500 MW capacity (http://www.rrecl.com/PDF/MOUSUZLON.pdf). Similarly, horticulture department of Rajasthan Govt. has been constantly devoted their efforts to install solar PV pumping system (3 HP and 5 HP capcity) in farmer's field for irrigation purpose (http://horticulture.rajasthan.gov.in/ContentDetail.aspx?pagename=National_Solar_Mission) and it was targeted to install 4702 solar pumps during 2015-16 with different subsidy schemes.

SOLAR PV TECHNOLOGY

Photovoltaics, also called solar cells, are electronic devices that convert sunlight directly into electricity (Fig. 4). The modern form of the solar cell was invented in 1954 at Bell Telephone Laboratories. Today, PV is one of the fastest growing renewable energy technologies and it is expected that it will play a major role in the future global electricity generation. The Photovoltaic effect is when two different (or differently doped) semiconducting materials (e.g. silicon, germanium), in close contact with each other generate an electrical current when exposed to sunlight. The sunlight provides the electrons with the energy needed to leave their bounds and across the junction between the two materials. This occurs more easily in one direction than in the other and gives one side of the junction a negative charge with respect to the other side (p-n junction), thus generating a voltage and a direct current (DC). PV cells work with direct and diffused light and generate electricity even during cloudy days, though with reduced production and conversion efficiency. Electricity production is roughly proportional to the solar irradiance, while efficiency is reduced only slowly as solar irradiance declines.

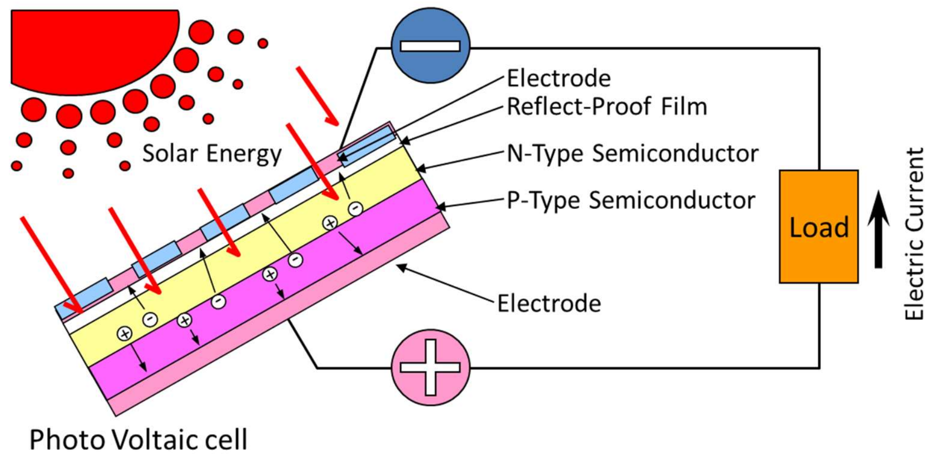

Fig. 4: The photovoltaic effect of electricity generation

A photovoltaic power generation system consists of multiple components like cells, mechanical and electrical connections and mountings and means of regulating and/or modifying the electrical output. These systems are rated in peak watts (Wp) which is an amount of electrical power that a system is expected to deliver when the sun is directly overhead on a clear day.

PV technology offers a number of significant benefits, including: (i) Solar power is a renewable resource that is available everywhere in the world; (ii) Solar PV technologies are small and highly modular and can be used virtually anywhere, unlike many other electricity generation technologies; (iii) Unlike conventional power plants using coal, nuclear, oil and gas; solar PV has no fuel costs and relatively low operation and maintenance (O&M) costs. PV can therefore offer a price hedge against volatile fossil fuel prices; (iv) PV, although variable, has a high coincidence with peak electricity demand driven by cooling in summer and year-round in hot countries.

A PV system consists of PV cells that are grouped together to form a PV module, and the auxiliary components (i.e. balance of system - BOS), including the inverter, controls, etc. There are a wide range of PV cell technologies on the market today, using different types of materials, and an even larger number will be available in the future. PV cell technologies are usually classified into three generations, depending on the basic material used and the level of commercial maturity:

- First-generation PV systems (fully commercial) use the wafer-based crystalline silicon (c-Si) technology, either single crystalline (sc-Si) or multi-crystalline (mc-Si).
- Second-generation PV systems (early market deployment) are based on thin-film PV technologies and generally include three main families: 1) amorphous (a-Si) and micromorph silicon (a-Si/μc-Si); 2) Cadmium-Telluride (CdTe); and 3) Copper-Indium-Selenide (CIS) and Copper-Indium-Gallium-Diselenide (CIGS).
- Third-generation PV systems include technologies, such as concentrating PV (CPV) and organic PV cells that are still under demonstration or have not yet been widely commercialised, as well as novel concepts under development.

SOLAR PV TECHNOLOGY FOR VERTEBRATE PEST MANAGEMENT

1. Solar Power Fencing Technology

The fence is like barbed wire fencing with multiple strands of plain wires and metal/cement/ wooden posts to hold the strands in position. The wires carry high voltage current. The Solar Power Fence gives a sharp, short but a non-lethal shock to the intruder and creates psychological fear, against any tampering. The alarm incorporated in the system gets activated and alert the inmates of the protected area. These are tailor made fences and can be designed according to customer needs and site condition.

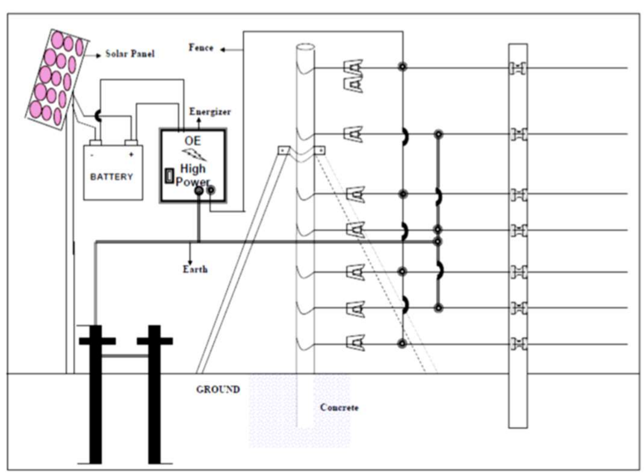

Fig. 1: Schematic diagram of solar fencing system

A solar panel is made up of a number of photovoltaic cells connected in series. Electricity is generated by these cells. Combined into a solar panel, these cells can produce enough voltage to charge a regular 12 volt battery. The solar panel ensures that the battery remains charged at all times. The battery stores the energy generated by the panel, and powers the energizer 24 hours a day. The energizer is the device which transform the low voltage current from battery to high voltage (upto 10,000 volts) current and send it to the electric fence. This way the fence is electrified and animals touching the fence receive the shock. Due to high voltage shock to the animals touching the fence, animals keep away from the fence and field is protected.

2. Solar powered bird scarer

The solar powered bird scarer is a device to scare birds away from different locations varying from large crop fields to airports and urban areas. This scare crow device uses natural bird distress calls to drive them away from crop fields and other populated areas. The device is powered by Photovoltaic Cells, also called solar panels. These devices are portable and water proof.

Fig. 2: Solar powered bird scarer

(Source: http://www.mechanicalengineeringprojects.net/solar-powered-bird-scarer/)

The bird movements over a wide area is detected by the device using infra red sensors. Once such a disturbance in the area is detected, the device produces distress calls to drive away the flock of birds. This system is very effective, portable and is independent of any external power supplies.

CONCLUSION

Solar PV technology has been proven as most widely adopting technology in India. As per national solar mission, 100 GW solar PV generation need to be achieved by 2022. Several large-scale grid-tied solar PV installations have been done and several others are in progress to meet out the target. Roof top solar installation has also become very popular since its ease in installation and meeting the domestic electricity need. Apart from these, agriculture sector may play a major role in this national solar mission target. Solar PV puming systems for irrigation, agrivoltaic systems, solar green house etc are the major areas in agriculture sector to contribute in renewable energy generation. In addition to generation, use of solar energy in different agricultural operations may replace the use of coal-based energy and thus makes the agriculture climate smart. Likewise, different solar powered devices and equipment may be used for control of pest and diseases. There is ample scope of using different innovative solar PV devices for pest and disease control e.g. solar PV duster, solar PV sprayer etc. Non-destructing methods of pest control may also be feasible for large vertebrate pest. Here, we have discussed two such devices, solar fencing and solar PV powered bird scarer. It is expected that in future, such renewable energy-based devices are to be used in a large scale for making the agriculture sustainable in the country.

CONSERVATION AND MANAGEMENT OF MONKEY POPULATION IN RAJASTHAN

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Rajasthan University of Veterinary & Animal Sciences, Bikaner

INTRODUCTION

Monkey menace in the agricultural crop and cities has been a matter of serious concern among farmers and people respectively. From Jammu and Kashmir and Himachal Pradesh in the north, to Karnataka and Andhra Pradesh in the south, farmers face huge crop losses due to attacks by monkey menace. Several cities, such as Varanasi, Haridwar, Mathura, Chandigarh, and New Delhi faces monkey attack related stories. In Rajasthan, Alwar, Jaipur, Sirohi, Jalore are area where serious conflict cases reported by forest department. In Marwar region, Langurs bite cases are more as compared to rhesus. Though many species raid cultivated crops (e.g. insects, rodents, birds, wild boar and nilgai), primates in particular can be significant pests because of their opportunism, adaptability, intelligence and manipulative abilities. The major crop raiding monkeys include Rhesus macaque and Hanuman langur. As far as farmer is concern, they often have limited access to cash and are rarely compensated for their losses, the individual economic losses suffered from crop-raiding can be relatively high. Furthermore, farmers' inability to mitigate crop-raiding adequately and the absence of compensation schemes may lead to retaliatory killing of problem species.

MONKEYS BIOLOGICAL ADAPTIBILTIES & REASON FOR MENACE

Rhesus monkeys (*Macaca mulatta*) are highly active and very loud. They enjoy being in water and are good swimmers. They live in groups of up to two hundred individuals. When a group's size reaches 80 to 100 members, a sub group of females may split off to form a new group. Populations generally consist of a few unrelated males and many closely related females. Sometimes small groups form that consist of only males. Males usually leave the group in which they were born shortly after they reach sexual maturity. Off spring born to a mother and son, or to siblings, are very rare. Both males and females in a group show a preference for high ranking members of the opposite sex. Dominance hierarchies exist in both sexes. This is far more evident in males, where competition for mates may occur regularly. The female members of a group usually live in complete harmony and rarely have violent interactions with one another. Although rhesus monkeys live in groups, they are not territorial. Each group of individuals usually has its own sleeping space, but the territories of neighboring groups may overlap considerably. Confrontations between groups are rare. Usually when groups meet, the weaker group will avoid the stronger group. Any confrontations that arise are because of an uncertainty concerning strength and dominance. Rhesus are more movable than humans, and are better at manipulating devices made for human hands – like handles, windows, and faucets. Like many urban animals, rhesus macaques' diet and environmental tolerances are flexible. Rhesus monkeys are mostly herbivorous, when food is abundant, they save it in specialized pouch like cheeks. They eat a wide range of food, including stems, shoots, leaves, grasses, eggs, insects, other invertebrates, soil, and fruit. Their diet varies from area to area and with the seasons. According to some authors, their reproductive cycle is timed to the availability of food in their environment, and in regions where there is a rainy season most infants are born at its end. About half of the rhesus macaques in the world live in India, and most of these monkeys (as many as 85%) live in close proximity to human settlements.

The Hanuman Langur (*Presbytis entellus*) is grey in colour with silvery shades. Their hands and feet are black and they have long tails for balancing on tree limbs. They are quadropedal and live both arboreally and terrestrially using their strong limbs to manoeuvre rapidly through their environment. Langurs have a specialized gut that allows them to breakdown cellulose from leaves, this allows them to have a wide range of habitats. They have a variable social structure but usually only one dominant male. Males will fiercely defend his females, while females will defend their resources. When a new male takes over a troop, he will usually commit infanticide, killing all the previous male's offspring, so that he may create his own faster. This reproductive strategy was first observed in this species. Langurs are also the first species documented to practice all mothering, when other members of the group help care for the infant. They are known for their whoop call which communicates spatial location and males have an additional six vocalizations unique to them. Langurs spend 80% of their time on the ground but will sleep in high trees. The female breeds at 51 months of age. Gestation lasts 200 days. They usually only have one young and weaning begins at 13 months. Births are spaced every 2 years or so. The infant is dark brown at birth and stays this color for 3-5 months. The infant clings to its parent unaided and are often carried by several females throughout its' infancy. Hanuman Langurs are considered sacred and worshipped in India. They are named after the Hindu monkey God, Hanuman, who is said to have burned his hands and face while rescuing a woman from a fire. This is why they believe the Langurs hands and face are black.

Monkey lost its basic requirements of space, shelter, and food as a result the conflict cases encountered more as compare to crop raid. As forest is cleared for agricultural expansion, human and wildlife habitats are overlapping. Rhesus monkeys (*Macaca mulatta*) and Hanuman langurs (*Presbytis entellus*) both live in temples, cities, towns, villages, on roadsides, and in forests. They have been worshipped, provisioned and protected by the

Hindus. Once monkeys take to demanding food, they soon graduate to stealing it. Failing to get food, they are known to attack. Many believe that the easily available food in cities is making monkeys lazier, and driving up their populations. Train stations and bus stations attract monkeys because of the large amounts of untended edible garbage that accumulate at such transitory locales. Rhesus macaques sometimes damage telephone wires, satellite dishes, antennas, electrical conductors, and other high-strung pieces of infrastructure. Roadways and bridges, areas of major concern to anti-terrorist agencies, are also attractive to some rhesus. In the city, such transport pathways are also bottlenecks, and restricted lines of movement allow gutsy monkeys the perfect setting for stealing food right out of the hands of passing humans. There is still an increasing need for a proper understanding of crop raiding, including inter specific and geographic differences in crop-raiding patterns. Studies revealed that the main reason for monkeys encroaching beyond the boundaries is

MANAGEMENT OF MONKEYS

The future of monkey populations is dependent on the nature of the pressures on their forest habitat, fire damage, grazing, ground litter removal and commercial plantation. The preferred habitats are becoming scarce due to this human activity, and adaptation of the rhesus monkeys, and to some extent Hanuman langurs, to non-forest habitats may lead to a deterioration of their relationship with people. Rhesus monkeys were engaged in significantly more feeding from human resources than langurs. On the other hand, langurs were engaged in significantly greater wild feeding than the rhesus. From this it is clear that rhesus monkeys would receive more harassment from humans than langurs. The more negative attitude of people towards rhesus is the result of the feeding strategy adopted by this species.

The rhesus and langur have different in term of food and habitat preferences and on the basis of their experiences and religious affiliations. Thus, villagers are more aggressive toward the rhesus, and the langur is considered as gentle creatures.

A conservation strategy beneficial for humans and monkeys is motivating villagers to plant wild fruit trees in their nearby forests and on the edges of fields. Translocation may be considered for non-forest populations facing inevitable disaster, but requires planning and research. Rhesus monkeys are occasionally trapped from Shimla, Kangra and Chamba cities, and carried to distant areas for release. Such urban monkeys reach nearby human habitations after a few days only to create havoc. Such translocations, although few, arouse false panic in the rural people that monkeys removed from towns are released near their villages causing ever more crop damage. Such false impressions may lead to the development of negative attitudes towards wildlife. Therefore, the involvement of the recipients of a translocated population is absolutely essential. The feeding habits of the monkeys may be another important factor. Translocation is advisable only between similar habitats. Plantation of fodder species may be beneficial both for primates and livestock. This will help reduce grazing pressure reported in almost all the national parks and sanctuaries. Lastly, the forestry policy of the future and the attempts to develop national parks and sanctuaries should take into account people's feelings, perceptions and attitudes in conservation and management plans.

Mitigating crop-raiding and monkey bite should thus explicitly target farmers and local people, as well as the macaques and their habitat, and requires individual involvement of and positive actions by local people for crop management. A key factor in this approach is to reduce the food resources available to macaques, such as crops (by proper protection), unharvested fruit, garbage and disposed vegetables, in and around human settlements so as not to attract the macaques to the area. In other areas, persuading primates to change their ranging patterns by offering artificial feeding stations away from human settlements may be a cost-effective solution. When proper protection of crops or effectively culling crop-raiding animals is not an option, the best techniques for deterring crop-raiding are often centred around influencing the behaviour of the raiding animal. These techniques may occur at any stage of the crop-raiding cycle. To be effective, deterrents need to alter the cost-benefit ratio of the raiding event. Simple and cheap deterrents, such as fences, guarding by people or dogs, throwing objects or making a loud noise, many of which are already employed in our study area, can be effective but probably only when used systematically. Deterrents work best when employed by the community as a whole, or at least concurrently by neighbouring farmers, on a continuous basis. We furthermore accept that while the conflict starts with actual damage caused by macaques, human relationships within the management process may result in more severe social conflict. Thus, relationships among stakeholders with different concepts of value (e.g. farmers, non-farming villagers, national park management and tourists) may be a social factor making conflict more serious. Even increased crop protection on one farm (e.g. better fencing, active protection or repellents) may inadvertently lead to social conflict among farmers as macaques may simply shift their raids to unprotected fields or adjacent farms. An integrative approach to reducing macaque–human conflicts is needed, an approach which not only adjusts interactions among macaques, habitat and humans but which also mitigates interactions among humans faced with the challenges of crop-raiding. The tendency of people holding ‘someone else’, attitude should be rise above and along with government bodies we will have to formulate basic guidelines for the solution of monkey populations, loss of species-specific habitats, habitat degradation and fragmentation, intensive agricultural practices, insufficient prey base and food material, increase in human and livestock population, competitive exclusion of wild herbivores, land use transformation, developmental activities, growing interest in ecotourism and increasing access to natural reserves.

ECO-FRIENDLY MANAGEMENT OF HIGHER VERTEBRATES WITH SPECIAL REFERENCE TO WILD BOAR

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Across the world, as human populations have expanded, wildlife species have been restricted to small patches and land has been transformed to meet human needs like settlement, cultivation, construction of roads, railways, and other infrastructure projects. Indiscriminate destructions and fragmentation of natural habitats, blocks migration routes, facilitates encroachment, and encourages poaching, all these factors cumulatively force the wildlife to restrict to small patches, thus resulting in severe conflicts between humans and wildlife. These changes often increase the potential for conflicts between wildlife and people that result in damage to resources and threaten human health and safety. Human-wildlife conflict has been a well-known problem in vicinities of protected and non-protected areas. Incidences of human casualties, livestock depredation and crop damage caused by wild animals e.g. elephant, tiger, lion, sloth bear, leopard, nilgai, deer and wild boar have been widely reported from various parts of India (Bargali et al., 2005, Chauhan, 2005a,b, Bargali, 2003, Manakanda and Rahmani, 1998, Mishra, 1997, Chandra. 1997, Rajpurohit, 1996, Saberwal et al., 1994, Indrukar et al., 1994, Sinha and jha, 1994, Chauhan and Singh 1990 and Schultz 1986). Many species (including elephants, rhinoceros, and tigers) are killed for international trade of their body parts. Although poaching is not a direct source of conflict, injured elephants and other animals (e.g., tigers) often retaliate by killing humans and damaging their property. The other important phenomenon due to crop raiding by different species of animals which led these activities increases conflict between farmers and wildlife throughout the world. Crop raiding by animals, in particular mammals like elephants (*Elephas maximus*), gaur (*Bos gaurus*), blackbuck (*Antilope cervicapra*), chinkara (*Gazella bennetti*), wild boar (*Sus scrofa*), Hanuman langur (*Semnopithecus entellus*), and porcupine (*Hystrix indica*) has been widely reported from all over the country (Prater, 1971; Schultz, 1986; Sukumar, 1990; Bohra et al., 1992; Balasubramanian et al., 1993; Chhangani, 1994; Chhangani, 2000; Chhangani and Mohnot,1997; Chhangani et al., 2002; Rao et al., 2015a,b).

The wild boar is one of the most widely distributed large mammals occurring in North Africa, Europe and Asia. Worldwide, there were 16 species of wild boars and wild pigs, the species present in India is Eurasian wild boar (*Sus scrofa cristatus*). It is distributed in almost all the states of the country. Wild boars are prolific breeders and apparently breed throughout the year. The reproduction period in wild boar is seasonal and mostly correlated with availability of food and other climatic factors. The males sexually mature between the ages of 5 and 7 months and females between 4 and 6 months. The males reach the sexual maturity in 15 and 24 months but they will not mate until they have reached their full size at five years of age, and females at 18 months of age. In recent years the species is majorly indulged in crop raiding and has become a major pest in agricultural ecosystem. Wild boars are omnivorous, living on crops, roots, tubers and carrion. Wild boars in general moves in groups and their activity is more during early morning and evening hours, peculiarly active at dawn & dusk than in the actual day period. They possess a unique feature of identifying cropped areas through their smell sensory mechanism. As per IUCN, wild boar is listed under 'least concerned' category, while it is under Schedule III of Indian Wildlife Protection Act 1972.

To date there has been comparatively little systematic research carried out to investigate patterns of crop raiding activity by wildlife and its potential impact on farmers' food and household economic security. The majority of the research that does exist has focussed on the issues related to crop damage by elephants and rodents, yet other animals such as primates, and ungulates, are often cited as troublesome 'pests' in agricultural areas all over the country.

Keeping in view the severity of the problem associated with the wild animal species, to minimize the crop losses and also farmer – animal conflict in agricultural landscape, ICAR has launched an All India Network Project on Vertebrate Pest Management during XII Plan period. Besides studies on birds and rodents, management of higher vertebrates is an important component of the Network; the AINP on Vertebrate Pest Management had extensively studied the behavior and pest status of the targeted species wild boar and developed some potential strategies to control the wild boar damage in agricultural fields. The methods are proved effective in several locations but need to evaluate in different agro-ecological regions of the country.

ECO-FRIENDLY COST-EFFECTIVE MANAGEMENT METHODS

1. Biological barriers

i. Use of four rows of Safflower as barrier crop: The practice of having 4-5 rows of safflower crop (high density) as border around ground nut found to be most promising in preventing the damage by wild boar. Safflower crop by being thorny in nature causes great amount of inconvenience and damage to wild boar especially under situations when it is sown in closed spacing (row to row 30 cm and plant to plant 10cm). In addition, safflower crop emits strong chemical odour effectively masking the odours emitted by ground nut crop. Due to this wild boar at the first instant fails in locating the ground nut crop, secondly even if it is locates the thorns of the safflower plant causes mechanical injury or damage, thereby they will not try to enter into the ground nut field. By using this, extent of damage by wild boar can be minimized to the level of 75 – 90% and also additional income realized through safflower crop comes as an added advantage to the farmer.

ii. Four rows of castor around the crop: This method is widely being popularized in maize and sorghum crop by planting 4-5 rows of castor with close spacing (high density with row to row 45cm and plant to plant 30cm) around the maize crop. Wild boars being capable of identifying maize only through smell can't do so owing to the strong odour emitted by the castor successfully masking the odour emitted by the maize crop. Damage in castor by wild boar is also not possible due to the non palatable nature of the plants with high amount of alcholodies and glucoscides. Through this method, a farmer is benefitted with additional income through castor. Usage of castor as border crop is practicable in both Kharif and Rabi seasons and the same crop can be used as border crop in crops like pulses and oil seeds. This method effectively controls the wild boar damage to the extent of 75-90%.

2. Physical barriers

i. Circular razor wire as physical barrier: The iron wire fixed with sharp razor blades at regular distance is kept 1 ft away from the cropped area as border by forming circular rings. The blades caused serious damage to the wild boar which tries to enter into the field. This not only prevents the animal to enter into the field but also scares away other animals. The entangled animal makes alarm calls which deter away the other wild boars thereby saving the entire crop without any damage. Implementation of this method reduced the wild boar entry into the cropped area to the extent of 70-85%.

ii. HDPE Nylon Fish net as physical barrier: The fish nylon net (HDP, UV stabilized, 2" mesh and 1.5mm thickness) using bamboo or strong wooden poles should be erected around the crop vertically for about 3 – 4 feet height. At every 10 – 15cm nails to be fixed on the poles for better fixing of the net. Insert the nylon rope in between the mesh net and fix horizontally on the ground by using small wooden pegs. This method prevents entry of the animal into the fields and also if by chance animal enters will be entangled and makes alarm calls which deter away the other wild boars. Erecting of fish net around the field reduce the wild boar damage to the tune of 70-90%.

iii. GI wire fence: A simple GI wire can also be use to create physical barrier for wild boars where three rows of GI wire fixed around the crop with the help of poles with a height of 1 feet from the ground level. This method is comparatively simple and economical method as compared to other barriers. The animals by coming in contact with GI wire feels threatened and gets scared away by confusing the GI wires with electric fences and reduce the damage caused to the extent of 55-70%.

iv. Barbed wire fence: Erecting of barbed wire around the field in three rows with first row being at the height of 1 foot from the ground. This is highly effective in preventing wild boars from entering into the cropped area to the extent of 60 -74%.

v. Chain link fence: It is an easy and most effective way of fixing a barrier which is more durable in nature. Chain link meshes of 3 feet height can be fixed around the crop by maintaining a distance of 1 ft away from the crop. This method can be used in seed production crops and also in various horticultural crops. By using this permanent physical barrier the extent of damage by wild boars reduced by 65-80%.

vi. Solar fence: This is a permanent type of physical barrier arranged around the cropped area which is gaining more popularity in the present times. This method is being widely practiced to prevent the damage by wild boar in high valued remunerate crops. In this method a solar fence is fixed around the crop with 12 volts electricity being sent to the fence with the help of solar plates. The shock received by the animal during the contact will not be capable of killing the animal but certainly ward off not only the animal which comes in contact but also other following animals which will be scared due to the alarm calls of the shocked animal.

3. Chemical and non-chemical methods

i. Spraying of egg solution: By exploiting the habit of the wild boar using smell of the crop as criteria for identification, an extensive level of experiments was carried out to use spray of egg solution either on the border row of the crop or on the wet soil around the crop. The results has given a clear cut indication that spray of egg solution 20 ml/lt of water was capable of successfully making the natural odour of the crop and thereby reducing the wild boar damage up to 55-70%.

ii. Use of Phorate / Thimet granules: Phorate / Thimet granules is having strong smell of chemical which is exploited under this method to mask the original smell of the crop acting as guiding source for wild boar attack. 200 gms of Phorate/Thimet mixed with 1 kg of sand is tied in perforated polythene bags and are arranged around the crop at the distance of 3 mts maintaining a height of 60-100 cm from the ground level. Slow release of the smell of Phorate/Thimet by wind currents through polythene perforation will prevent successfully the wild boar attack. As in earlier cases strong smell of Phorate/Thimet will also help in the masking of natural smell of the crop, there by confusing the wild boars in locating the crop and reduce the damage up to 50-65%.

iii. Arrangements of coconut ropes soaked in mixture of sulphur + pig oil: Arrangement of coconut rope in three rows around the crop by keeping 1 ft distance between the rows with the help of wooden poles can be done. Preparation of solution with sufficient quantity of sulphur is mixed with local /domestic pig oil is done and that mixture should be smeared on the arranged coconut ropes. This mixture generates the typical smell there by repelling wild boars not to enter into the cropped area. For an effective use of this method two such applications should be done with ten days interval in between, this method is effective up to 60-80%.

4. Traditional methods

i. Human hair as respiratory deterrent: Wild boar with poorly developed sight and hearing mechanism has to depend on its smell sensory mechanism only for movement as well as locating of food. In this process it moves from one place to other place only by a way of sniffing on the ground there by getting guided in to the desired routes. Spreading of human hair collected from local barber shops is an affective and low-cost traditional method being followed by farmers. Technically this indigenous method does have scientific logic which clearly suggest that the human hair in the movement routes wild boar gets sucked through nostrils causing severe respiratory irritation. Due to this the wild boar gets totally disturbed and loses its track by making distress calls, which will ward off other wild boars entering into the cropped area. Several farmers are extensively practicing this method in different crops and controlling the damage caused by wild boar to the extent of 70-80%.

ii. Fixing of used colored sarees: This method also is a farmers' innovation, which has a behavioural background as far as wild boar is concerned. By arranging used sarees of different colors around the crop will make wild boars to assume human presence in the area there by not preferring to enter into such areas. Even though, not feasible in all situations it has some marginal benefit in the areas of human movement. By using this, extent of damage by wild boar can be minimize to the level of 45-60%.

5 Bioacoustics

The bioacoustic technology uses only sounds of predators, distress and alarm calls of target and closely related species of target animals. The calls are broadcast in a field by suing an electronic platform with sound drives. Bioacoustic tries to convey the message 'this area is dangerous' to the target animals in their own language. On hearing the sounds, the target animals start avoiding the area, thus saving the crop from being damaged. The sounds are natural and safe on humans, birds and animals. The equipment produces fixed volume of 110 dB at source covering an area of 4-5 acres when ambient noise level is around 42 dB. At 37 dB of ambient noise, the equipment can cover up to 19 acres. The equipment should be ideally installed when the animal damage is beginning. Bioacoustics is 92% effective in dispersing wild boar from the cropped area.

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Castor (four thick rows) around the maize crop

Safflower (four thick rows) around the Ground nut crop

Circular razor fence around the crop

Chain link fence around the crop

Barbed wire fence around the crop

HDPE Nylon fish net around the crop

Spraying of egg solution around the crop bunds

Arrangements of Coconut ropes soaked in mixture of Sulphur + Pig oil

Use of Phorate / Thimet granules

Spreading of human hair as thin layer around the crop

Fixing of used coloured sarees as border around the crop

Installation of bioacoustic equipment in field

CHIROPTERAN (BATS) DIVERSITY AND ITS SIGNIFICANCE TO FARMERS

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Chiroptera, commonly known as bats, is among the 29 extant mammalian Orders (Wilson and Reeder, 2005). Order Chiroptera includes about 1300 extant species of the bats world over in preferably two unequal suborders, the Megachiroptera (Old World Fruit Bats) Consisting 186 species of old world fruit bats in one family and the Microchiroptera (echolocating bats) consisting of 931 species in 16 families (Molur et al., 2002; Simmons, 2005).In India, currently, we have 127 species of 40 genera, and nine families constitute almost 10% of global bat diversity (Saikia, 2018). In many countries' bats are major contributors to mammalian biodiversity, while in some, particularly small oceanic islands, they are the only indigenous mammals and play a vital role as "Keystone" species in ecosystem. More than 20% of all known mammal species of the world are bats.

On the basis of their morphological, anatomical, physiological and aerial adaptations bats are subcategorized in to two suborders viz., Megachiroptera and Microchiroptera. The Megachiroptera (consisting of a single family, the Pteropodidae or Old-World fruit bats) are found in the Old-World tropics and sub-tropics from Africa through southern Asia to Australia and on islands in the Indian and Western Pacific Oceans. Microchiropteran bats are found in all parts of the world except Arctic, Antarctic, some extreme parts of deserts and few isolated oceanic islands (Hutson et al., 2001).

Being representatives of second largest order of class Mammalia bats show extensive adaptive radiation in size, habit and diet. So far as, the feeding habits of chiropterans are concerned, majority of them, including most of those in the suborder Microchiroptera are insectivorous, although some are carnivorous, a few are piscivorous, and three species of vampires are sanguivorous. Bats of the Old-World suborder Megachiroptera are predominantly frugivorous, but also consume nectar, flower, leaves and occasionally insects. The New World family Phyllostomidae has a similar plant diet, but some species may incorporate a greater proportion of insects compared to Megachiroptera.

Bats are the only mammals with the capacity for powered flight (Altringham, 1996), and the Microchiroptera, together with the Megachiropteran genus Rousettus, have evolved a system of echolocation, by means of which they orient themselves and find their path and food, and have enabled them to roost in situations where light intensity is low. In addition, those species living in temperate latitudes are heterothermic and hence are able to adapt to food shortage during winter by hibernating with their reproductive cycles modified. The most notable reproductive adaptation is a delay in fertilization: mating generally takes place in autumn and spermatozoa are stored in the female reproductive tract until ovulation occurs in the following spring (Racey, 1999).

The bats are sensitive to habitat disturbance and landscape changes from anthropogenic events and might be used as indicator species Purohit et al., (2013) and Wordley et al., (2017). Studies have been proposed since 1963's to till date Prakash (1963), Sinha (1979; 1980; 1981 and 1996), Bates et al.,(1994), Purohit and Kaluram (2001), Purohit et al., (2002; 2006; 2012 and 2013), Senacha (2003), Dookia (2004), Purohit and Senacha (2002; 2003 and 2004), Purohit and Vyas (2006), Srinivasulu et al., (2013).

The data collected on chiropteran diversity in Rajasthan state reflects 26 bat species of 8 family and 19 genera. Among them, three are Megachiroptera i.e. *Cynopterus sphinx sphinx, Pteropus giganteus giganteus*, *Rousettus leschenaultii leschenaultii* and twenty-three are Microchiroptera species i.e. *Rhinolophus lepidus monticola, Hipposideros fulvus pallidus, Hipposideros lankadiva, Asellia tridens, Megaderma lyra lyra, Rhinopoma hardwickii hardwickii, Rhinopoma microphyllum kinneari, Taphozous longimanus longimanus, Taphozous melanopogon melanopogon, Taphozous nudiventris kachhensis, Taphozous perforatus perforatus, Tadarida aegyptiaca thomasi, Chaerephon plicatus plicatus, Eptesicus serotinus pachyomus, Hesperoptenus tickelli tickelli, Scotophilus heathii heathii, Scotophilus kuhlii kuhlii, Pipistrellus tenuis mimus, Pipistrellus ceylonicus indicus, Scotozous dormer, Barbastella leucomelas darjelingensis, Myotis blythii blythii,* and *Kerivoula picta picta* inhabiting in various parts of the Rajasthan.

There are several ways in which bats can be considered to be of economic importance. Bats have a tremendous role to play in ecosystem, a very simplistic example being fruit bat's role as "flower pollinator and in seed dispersal", and that of insectivorous bats in "controlling much of the insect pest population". Although fruit bats damage a small percentage of agricultural crops, their role in forest regeneration more than compensates this loss in the long-term from the prospective of the greater good.

FLOWER POLLINATOR AND IN SEED DISPERSAL

Bats play important role in the pollination and seed dispersal of many tropical plants. In the Neotropics, Phyllostomid bats act as seed dispersal agents for up to 24% of forest tree species at some sites (Humphrey and Bonaccorso, 1979). It is thought that phyllostomid bats become increasingly important as dispersal agents in wetter forests.

Bats may also play a key role in pollination of plants. It has been estimated that bats play some part in the pollination of at least 500 Neotropical species of 96 plant genera. The importance of phyllostomids as pollinating agents increases in drier habitats. There are over 100 phyllostomid species that are responsible for dispersing seeds or pollinating plants, many of which are commercially valuable. For example, Seba's short-tailed fruit bat (*Carollia perspicillata*), one of the commonest bats in Latin America, plays an important functional role in tropical rainforest. The majority of diet is fruit from shrubs, particularly those of genus Piper and early successional plants. In a typical night, an individual *Carollia* eats about 35 Piper or 8 to 10 *Cecropia* fruits. It moves relatively to short distances before consuming these fruits, with the result that most seeds are dispersed close to the parent plant. Each bat may eat up to 60,000 seeds in a night; a colony of 400 could disperse 146 million seeds annually. Even if only 0.1% of these germinate, that represents 146,000 seedlings (Fleming, 1988). Overall, frugivorous bats play an important role in the regeneration of forests in disturbed habitats. In the Neotropics, bat-dispersed plants, such as Cecropia, Piper, Muntingia, Solanum, and Vismia, are among the first and most abundant species to invade natural and human made clearings (Hutson et al., 2001).

The association between bats and flowers is mutualistic. Plants divert energy into production of odours and floral parts that attract bats, as well as nectar and pollen to feed them. By moving flower to flower, bats transport pollen that results in fertilization. Many Neotropical phyllostomids are important pollinators, including the whole of the subfamilies Glossophaginae and Lonchophyllinae. A good example is bats of the genus Leptonycteris, which are the main pollinators of century plants (*Agave* spp.), from which tequila is produced. Such bats are probably integral to the maintenance of arid habitats (Arita and Wilson, 1987). The threatened Leptonycteris curasoae is thought to play an important role in pollination of cardon (Pachycereus pringlei) and organ pipe (*Stenocereus thurberi*) cacti in the Sonoran Desert in Mexico (Fleming, 1989). Flower drop-off rates were shown to be particularly high for organ pipe cacti, possibly due to the limited availability of Leptonycteris as a nocturnal pollinator. It is believed that the stigmas of organ pipe flowers are only receptive to pollen at night. This suggests a close dependence between the cacti and its bat pollinators (Fleming, 1989).

Many of the plants that benefit from pollination or seed dispersal by bats are economically important to man (Wiles and Fujita, 1992). At least 443 products useful to man derive from 163 plant species that rely to some degree on bats for pollination or seed dispersal. These products include timber, fruits, fibers and tannins that contribute significantly to world markets as well as, to lesser well-known products, such as medicines and food items important in local economies. The increasingly popular durain fruit (*Durio zibethinus*) depends on bats for pollination, as does petai (*Parkia speciosa* and *P. javanica*) whose seeds are popular food items in South East Asia. Fujita and Tuttle (1991) estimate the monetary value of these and a third product (the fruit of duku – Meliaceae: *Lansium domesticus*) to exceed $US4 million annually in Indonesia. Annual sales of petai are estimated to exceed $US1 million in Peninsular Malaysia alone. Twelve tree species dependent on bats for dispersal are major timber species in Malaysia, one of the major timber exporters in the world. The kapok or silk-cotton tree (*Ceiba pentandra*), the fiber, bark and seeds of which are economically important, is pollinated by a large number of bat species in Africa and South America, but pollinated solely by *Pteropus tonganus* in Samoa (Toledo, 1977).

Throughout the tropics, the seed dispersal and pollination activities of fruit- and nectar-eating bats are vital to the survival of rain forests, with some bats acting as keystone species in the lives of plants crucial to entire ecosystems. Many plants bloom at night, using unique odors and special flower shapes to attract bats. The famous baobab tree of the eastern African Savannas is a good example. Only bats approach from below in a manner likely to contact the flower's reproductive organs and achieve pollination. Of course, they do so because the plant rewards them handsomely with nectar. This tree is so important to the survival of other kinds of wildlife that it is often referred to as the "Tree of Life." Wild varieties of many of the world's most economically valuable crop plants also rely on bats for survival. Some of the better-known commercial products are fruits such as banana, breadfruit, avocados, dates, figs, peaches, and mangoes. Others include cloves, cashews, carob, balsa wood, kapok (filler for life preservers), and even tequila. Most of the plants from which these products come are now commercially cultivated, but the maintenance of wild ancestral stocks is critically important. They are the only source of genetic material for developing disease-resistant strains, rejuvenating commercial varieties, and for producing new, more productive plants in the future. The value of tropical bats in reforestation alone is enormous. Seeds dropped by bats can account for up to 95 percent of forest regrowth on cleared land. Performing this essential role puts these bats among the most important seed-dispersing animals of both the Old and New World tropics (Mickleburgh et al., 2002).

CONTROLLING MUCH OF THE INSECT PEST POPULATION

The majorities of bats are insectivorous in nature and are the primary consumers of nocturnal insects. They are serious pests for variety of crops and thus play essential roles in keeping population of night-flying insects in balance in many parts of the world. Just, one bat can catch hundreds of insects in an hour, and large colonies catch tons of insects every night, including beetle and moth species that cost farmers and foresters billions of rupees annually, not to mention mosquitoes in our backyards.

Some species of bats consume very large quantities of insects. For example, in the USA, *Tadarida brasiliensis*, which can roost in colonies numbering 20 million, may ingest 50-70 % of its body mass per night (Kunz et al., 1995) and *Myotis lucifugus* as much as 100 % (Kurta et al., 1989). In Texas, McCracken (1996) estimated that one million nursing *Tadarida brasiliensis* could eat over 10 tonnes of insects each night. In a study in southwestern Ontario, Canada, little brown bats (*Myotis lucifugus*) fed predominantly on mosquitoes, with 85 % of faecal samples containing mosquito remains, suggesting that this species could play an important role in the biological control of insect pests. Bats also consume a variety of other insects including Lepidoptera, Coleoptera, Homoptera, Hemiptera, and Trichoptera (Kunz, 1974; Whitaker et al., 1977; Kunz et al., 1995).

Bats are predators on a number of economically important insects, including cucumber bugs (Diabotrica sps.), June bugs (Phyllophaga sps.), and corn borers and Jerusalem crickets, which important agricultural pests on crops such as corn, cotton and potatoes (Whitaker, 1993). McCracken (1996) details work on the high-altitude feeding of *Tadarida brasiliensis* in Texas. He suggests that bats fly at heights of up to 3,000 m and intercept the high-altitude migrations of agricultural pests, particularly the corn earworm moth, which is the most important pest in America. A conservative estimate for a colony peaking at 50 million *Tadarida brasiliensis* was 6,700 tonnes over a 120-day summer feeding period (Hill and Smith, 1984). Another calculation for the same colony put the figure at 13,000 tonnes, though these are much lower than the figures suggested by McCracken (1996). The bat population using Niah Caves in Sarawak on the island of Borneo was estimated to consume 7,500 kg of insects every day (MacKinnon et al., 1996). What is certain is that bats do consume huge quantities of insects, some of which are considered pests.

Some insectivorous bats also eat small mammals. Indian False Vampire bat (*Megaderma lyra*) has been described as a "good friend of farmers" in the state of Bihar. Colonies of this species, ranging from 25 to 240 individuals, consume rats and mice, which destroy different grains stored in bags and are rewarded with protection by farmers, who call it as goddess "Laxmi" (Sinha, 1986).

VALUABLE BIOFERTILIZERS (GUANO- EXCRETA OF BATS)

Guano of bats is also considered as a valuable bio-fertilizer for many of the agricultural crops. Some of the largest bat colonies in a cave contain millions of bats, which produce large quantities of guano. In some sites, such as Carlsbad Cavern in New Mexico, guano mining was an economically important activity in the early part of the 20th century. By 1923, it was estimated that 101,600 tonnes of guano had been removed from Carlsbad (Geluso et al., 1987). In the recent years, the increased use of artificial fertilisers has led to a decline in the use of bat guano in developed countries. It is still, however, an important source of revenue for communities in the developing world.

Overall, it is worthwhile to say bats as one of the vertebrae of the agro-economy backbone of any country. By consuming thousands of insects in a night, microchiropteran bats help the farmers to save millions of rupee annually, whereas, megachiropteran bats which are frugivorous in nature, play a vital role in the seed dispersal mechanism of various plant species. Apart from this, these are the immense source of natural bio-fertilizer in the region. In fact, guano of these animals, which they scatter over the crop fields of the region during their foraging activity, is full with the micronutrients like phosphate and nitrogen derivatives and helped a lot to enhance soil fertility. In fact, these bats are ally to farmers.

RESEARCH MODEL

Other than these, ecological values studies of bats have also contributed to the development of navigational aids for the blind, birth control and artificial insemination techniques, vaccine production, and drug testing, as well as to a better understanding of low-temperature surgical procedures (Tuttle, 1988).

THREATS TO BATS

Many of the threats to bats can be directly related to increasing human populations that bring extra demands for land, food and other resources that ultimately results in the degradation or destruction of habitat for bats and other organisms. This pressure is especially acute in tropical countries where large proportions of the population live in rural areas and have relatively low incomes. One of the most important, but, universally threatened habitats for bats is forest or woodland used for roosting and feeding. While, much attention has focused, on the loss of primary forest in tropical and subtropical areas, the situation in temperate area is equally serious in many cases. Some harvesting techniques can be particularly damaging to the forest structure and logging activities may open up, previously, inaccessible areas to hunters, settlers and minors (Mickleburgh et al., 2002). Landscape elements are important for bats (Verboom, 1998). Tree lines, hedgerows, canals and other linear elements are used by bats during flight and may provide vital connections between roosts and feeding areas and their loss or disruption because of intensified agricultural practices. This proves to be highly detrimental to some species. In areas, where agriculture has been practiced at a less intensive level, such as in Central Europe, the threat to these cultural landscapes is a great concern for the conservation of bats and other organisms (Mickleburgh et al., 2002).

Worldwide, agriculture has had a major impact on many bat habitats. The negative effect of ‘slash and burn’ agriculture on bat population have recently been seen in Laos, where the nomadic people of the Nam Et Highlands burn primary forest to plant crops. Slash and burn destroys vegetation cover and may also kill individual bats that use tree crevices as roosts, affecting many of the threatened species of bats. Pesticides usages in agriculture in the developed world have recently moved towards chemicals with reduced mammalian toxicity, but highly toxic alternatives such as DDT are still used in developing countries (Fenton and Rantenbach, 1998). DDT has been widely used in Africa as a way of controlling the Anopheles mosquito, which spreads malaria (McGinn, 2001). Safer pyrethroid alternatives are now being used, although the use of DDT has been reintroduced in areas where resistance to pyrethroids has developed (McGinn, 2001). Such pesticides have been causing the decline of bat population in the USA and Australia. Clark (1981) and McWilliam (1994) showed that spraying with DDT increased the mortality of some bat species in Zimbabwe. Clearly, the threat to bat populations from DDT needs to be weighed against the threats to humans from malaria.

Natural events can also cause problems, especially on small islands in the Indian and Pacific Oceans that are regularly affected by tropical storms. A typhoon that hit Samoa and American Samoa in 1990 had severe impact on population of Pteropus tonganus and P. samoensis (Dashback, 1990). Following the storm many bats foraged on fallen fruit or in fallen trees, because bats were unable to take flight from the ground, they were vulnerable to predation and were killed in large numbers by domestic dogs, cats and pigs. Evidence from the Mariana Islands, Samoa and Vanuatu suggests that a major cause of post-storm mortality was increased hunting by humans (Pierson and Rainey, 1992). Defoliation made roosting animals more visible and reduced food supply forced bats to forage diurnally, increasing opportunities to hunt them.

Woodland management practices can also negatively affect bats. Removal of dead trees or decaying branches from living trees can reduce the availability of potential roosting sites. Bats may be loyal to an area containing several roosts rather than a specific tree, suggesting that even trees not heavily used by bats may be important for them (Barclay and Brigham, 1996; Pierson, 1998).

Underground sites such as caves and mines are crucial to the survival of many bat species, worldwide. In temperate countries, such sites may be used for breeding in summer and hibernation in winter, whereas in tropical countries, where bats do not hibernate, caves and mines may provide roosts for large colonies. In areas with few natural caves, such as Australia, mines provide important alternatives roost sites (Phillips, 1990).

Abandoned underground mines may be threatened by resumption of activities such as open cast mining, and the sealing of abandoned workings, usually for safety regions, can have a dramatic impact on bats. In Wisconin in the USA more than 6,00,000 bats of four species were saved when two mines were protected from closure (Tuttle and Taylor, 1998). Quarrying, particularly for limestone, is a major threat to caves in Asia. Samanar hill in Southern India has many caves used by bats, and only the canceling of new quarrying leases has saved the site (Murphy, 1987).

Some of the larger bat colonies produce sufficient guano, for it is an important economic resource, and uncontrolled guano collection can result in disturbance of these colonies. A similar problem exists, where bats share caves with cave swiftlets. The nests of cave swiftlets are highly prized as a component of bird's nest soup, with the most valuable nest worth US $ 2,000-4,000 per kg (Sankaran, 2001). Uncontrolled nest collection can disturb bat colonies, and concerns have been shown over dramatic decline in populations of naked bats *Chierometes torquatus* in caves in Sarawak (Mickleburgh et al., 2002).

Somewhere, caves are also attractive to speleologists and tourists. Spectacular cave systems are a magnet for tourists, and poorly managed tourism can modify cave ecosystems and adversely affect bat populations. In a number of countries such as UK and Australia there are agreements between conservationists and speleologists to minimise impact on cave ecosystems (Hutson et al., 1995; Watson et al., 1997).

During last few decades, the Thar Desert has witnessed tremendous human activities because of population explosion and introduction of IGNP (Indira Gandhi Nahar Pariyojna), earlier Rajasthan Canal. The IGNP has changed fauna and flora of this region and especially those, on the side of the canal. It has undergone phenomenal eco-transformation with dry land turning into wet in several parts of the Thar (Rahmani, 1997). The population explosion in this region has generated several new challenges towards the habitats of bats therein and thus has affected the eco-status of bats in this region.

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ROLE OF CONTRACEPTIVE IN MANAGING OVER ABUNDANT WILD ANIMAL POPULATION: CURENT KNOWLEDGE AND FUTURE SCOPE

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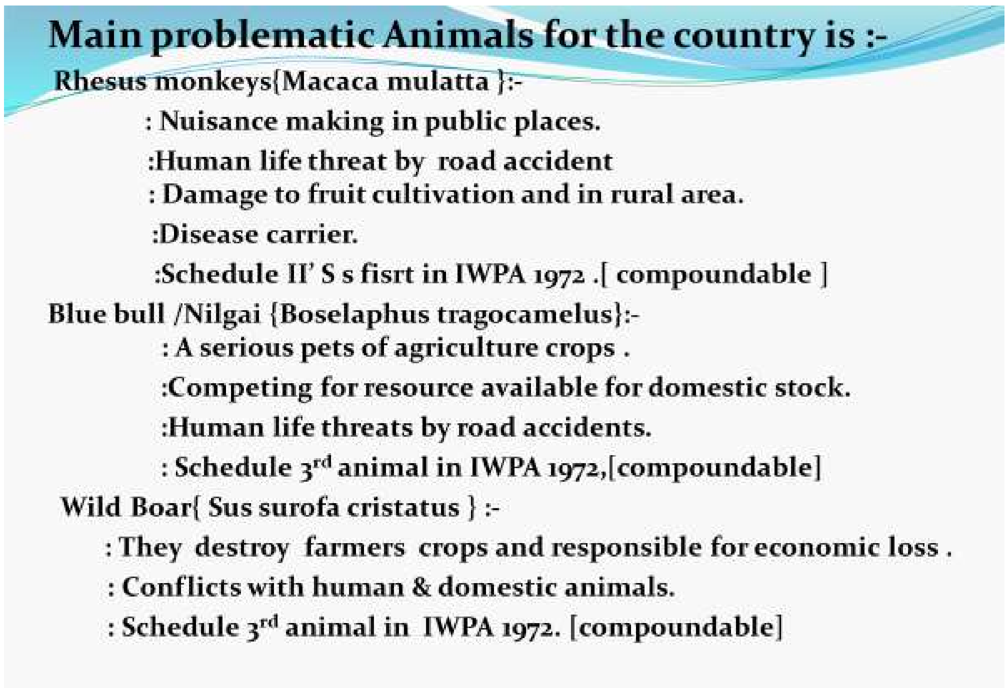

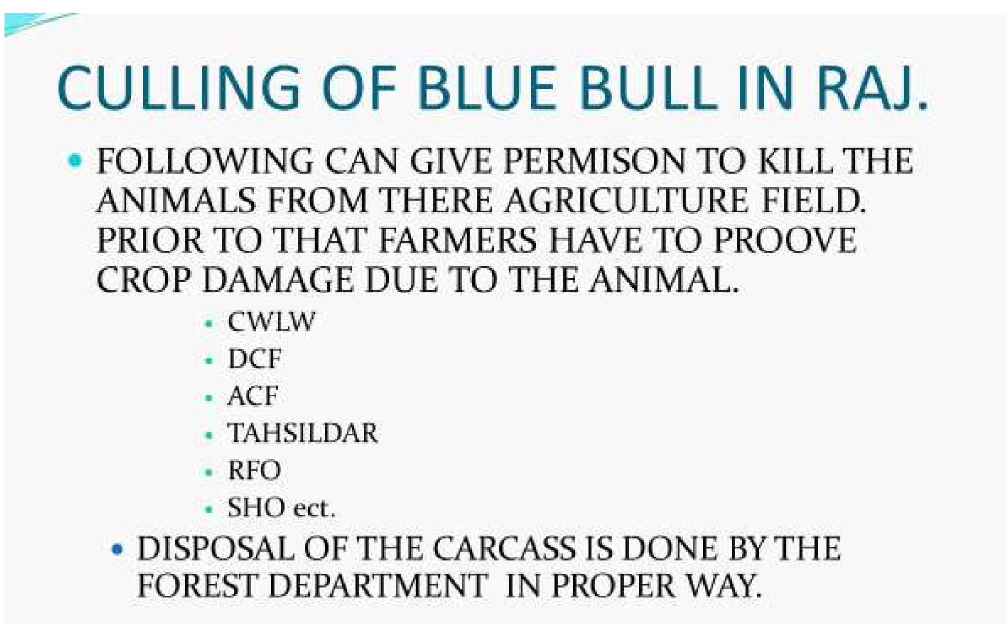

POPULATION MANEGEMENT STRETAGY

TRADITIONAL POPULATION CONTROL METHOD :-

1.Vasectomy.

2.Tubectomy\Ovariohysterectomy.

3.Casretion.

4.Separetion of breedable male and female apart.

5.Developed corridors between nearby forest to provide free movement of the over abundant population.

6.Traslocation of the surplus animals by Boma technique.

MODERN FERTILITY CONTROL METHOD :-

1. Immunocontraceptive Vaccine against Zona pellucida.

2. . Immunocontraceptive Vaccine against sperm surface antigens.

3.GnRH vaccine.

4.GnRH Agonist and Antagonists etc.

5.Endocrine suppression by synthetic hormones {progestin} etc.

FERTILITY CONTROL METHODS

- Its a more human method to control animal population .
- Causes temporary to permanent sterility in both the genders .
- Produce no undesirable side effects to the target species {no behavior or social change }.
- Needed study of :

  -Reproduction pattern,

  -Sexual behavior,

  - Hormonal profile during estrus cycle.

  -Characterization of gametes specially protein profile of Zona pellucida and sperm surface antigens of target species .

GnRH ANALOGUE BASED CONTRACEPTION

- Administration of GnRH analogue implant.
- Result in LH and FSH release..... subsequently sharp drop in concentration result in cessation of follicular development and spermatogenesis.

STEROID BASED CONTRACEPTION

Combination of Estrogen and Progesterone administration to the animal body by penetration leads to tricking the body in to believing it is already pregnant.

Plasma level of Estrogen and Progesterone remain constant throughout the treatment ,it leads to failure to produce Estrogen and LH peak due to that no ovulation occur .

Melengestrol Acetate implant available and its work for more than two years.

IMMUNOCONTRACEPTIVE VACCINE

- Principle of contraceptive vaccine is to use body's own immune system to induce immune responses against reproductive cells {gametes} or protein essential for implantation of a fertile egg leading to infertility.
- Porcine{Pig} zona pellucida is injected in to other animals than antibodies are produced and attached to that host animal's zona pellicuda and prevent the sperm to attaching to the ovum and stop fertilization process.
- The Zona pelicuda vaccine can work for more than three years.
- Vaccine against sperm surface antigens ,it will binding to sperm membrane and impaired its function{panetration in ovum}.

VACCINE DELIVERY BY DARTGUN

Capturing the free ranging animals to deliver the contraceptive vaccine by intra muscular route is expensive & lengthy task.

Following methods can be useful to dart :-

-Immunization of free ranging large mammals by dart-gun has been very useful.

-Trapping cages with appropriate bait and lures.

-Ambush nearby animals movement path.

-Use of silent motor vehicle.

-Use of helicopter to dart the vaccine.

VACCINE DELIVERY BY ORAL BAIT TO SMALL MAMMLAS

- Vaccine delivery by dart gun is not desirable for small free ranging animals such as monkeys as the dart may hit some sensitive and vital part of the body.
- For small mammals contraceptive vaccine may delivered by oral baits.
- However delivery of contraceptive by oral rout can have adverse consequences on the fertility of other nearby animal species, who may also consume these baits beside target species.

TO OVER COME THE PROBLEM BY TRADITIONAL HUMEN METHODS..

- TO AVOID LOW HEIGHT CROPS.
- LIVE FENCING WITH EUPHOBIA/THOR.
- FENCING WITH SHINING AUDIO TAPS.
- USING EXCRETA OF DONKEY ,BLUE BULL AND COW URIN FOR FOUL SMELL.
- SPRAYING PHENYL SOLUTION.
- BEATING BELLS .
- CRACKERS.
- SCARECROWS etc.

TT,CARE AND REHEBILITATION OF INJURED BB AT WLRC JODHPUR..

- JUN 2007WILDLIFE RESCUE CENTER STARTED BY WILDLIFE DIVISON FOREST DEPT.
- PER YEAR WE RECEIVE AAPROXIMATELY 400 TO 500 CREATICALY INJURED BLUE BULLS.
- COUSE OF INJURIESE IS :-
  - FERAL DOG BITE
  - ROAD ACCIDENT
  - FALLEN DOWN IN DRY WELL,TRENCHES.
  - TRAPPING IN BARBED WIRE FENCING etc.

NON-CHEMICAL METHODS OF RODENT MANAGEMENT

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Different methods exist in controlling rodents. However, each method has its own limitation. The methods that are in vogue and limiting factors are given below:

ENVIRONMENTAL AND CULTURAL METHODS

These methods are primarily based on ecological concepts wherein the rodents' habitat is manipulated in such a way that creates stress among native rodent pests. The methods are low cost treatments and involve little modification in crop husbandry practices, like ploughing, puddling, removal of wild vegetation and refuge of previous crops and reduction in bund size. It helps in migration of pest rodents from crop fields. Weed removal as a routine practice by the farmers in the crops also deprives harbourage and alternate food for the rodents. Moreover, the habitat stress created by these practices enhances the chances of rodents falling prey to predators. In sugarcane crop adoption of techniques like bunching of standing canes indirectly help to prevent rodent damage. Although no truly rodent resistance variety is available world over, however the sugarcane varieties with a thin cane, soft rind, low fibre and lodging type are more damaged by rodents. Similarly, early maturing varieties of rice are more prone to rodent attack. Synchronous sowing / transplanting in larger areas also reduce the rodent damage to a greater extent.

Sharma and Rao (1989) reported reduction in bund dimensions, viz., height and width resulted in decline in rodent infestation in rice fields. Alley planting in rice also reduces the rodent damage Physical elimination of the field rats is in vogue by certain communities in parts of the country. Irulas of Tamil Nadu, Erukulas of Andhra Pradesh belong to this category using rats for food purpose. Sometimes, they employ fumigation by indigenous method by smoking haystack in to their burrows. However, often the physical killing is done around ripening of the crop after the crop gets maximum rat damage. An improvised smoke generator (burrow fumigator) was developed by Acharya N.G. Ranga Agricultural University, Hyderabad for effective control of burrowing rodents. It involves burning of farm wastes like paddy straw leading to generation of smoke, which is pushed into the burrow tunnel with the help of blower (Rana and Tripathi, 1999).

PHYSICAL METHODS

Trap Barrier System (TBS): TBS is being tried in different countries employing fences to the rice farming and fixing traps at different intervals. Trap crop is also is added to attract rats to immigrate by growing a small patch of the crop on the periphery. This technology is considered to be effective, environmentally friendly, and do not trouble the rice crop. For construct TBS requires 1). Live traps (function: to collect rats, made up of metal mesh, possess 25cm(H)x25cm(L)x50cm(deep) of holes with cone shape entrance, placed on one sides of trap (wonder trap). 2). Plastic barrier (fence): the plastic fence act as a barrier for rats, during their navigation toward food search/lure crop; fence plastic barrier is a minimum of 60cm above the ground and dug 10cm into ground with bamboo poles inserted at every 1.5 M distance. Plastic fence with 60 cm height bears hole as the entrance to the live traps, and place/locate barrier inside at 20M of distance. Outside the barrier (all 4 sides) make trench and fill with water constantly (moat) and make mud channels (earth mounds partway) for assess rats toward holes of plastic fence then live traps (barrier). 3). Trap crop: is the rice plants planted three weeks earlier from surrounding/neighbouring crop to attract rats into the TBS. Trap crop (lure crop) 100Mx100M (1hactor) size advisable per 10 hectors required (50Mx50M (0.5hactor)/10hactor also preferable) and this size block require earlier plantation to surrounding is required. Total 16 live traps required for above size TBS at 20m distance (including 4 sides); Additional traps may establish up to 10no depending on rat population and infestation. This method will work for individual (TBS) and campaign mode (CTBS) effectively.

Precautions & maintenance:

- Multiple-capture traps must be well constructed to minimize trap shyness, especially the cone through which the rats enter
- Traps must be flush (close) with the fence – rats will use any small gap to enter the enclosure or gnaw to enlarge any small holes
- Good access to the trap entrance – construct earth mounds partway across the moat, leading to traps
- Plant the lure crop 2 to 3 weeks before the surrounding crop
- Empty the traps early each morning
- Check the plastic barrier for holes each day and either repair these or install extra traps at the holes
- Keep the moat free of grass (rats can use this to climb over the fence), & fill with appropriate water level
- Cover traps with straw and supply food to keep rats in good condition (the smell of dead rats will discourage other rats from entering traps)

Field studies conducted by AINP on VPM, Maruteru centre revealed that erection of TBS in paddy nurseries has attracted more rodent population, especially lesser bandicoots from the surrounding fields, consequently pressure on main crop after transplanting is minimized to a great extent. Farmers can adopt Linear Trap Barrier System (LTBS) in the place of TBS to minimize the costs as it was equally effective as TBS, when applied in a scientific way i.e. migratory side of the animals.

Trapping: Trapping is one of the oldest methods of animal control. A variety of traps can be used against rodents- live or snap. The efficacy of trapping, whether live or snap trap, depends on operational conditions of the trap, number of traps set, type of bait, place and time of placement. Scientific literature has seldom proved trapping as effective method against rodents as a measure of reducing their numbers. However, they can be employed in controlling localized infestations effectively. Tanjor kitties, bamboo Palmyra traps are highly effective for localized infestations. They help in maintaining rodent numbers at a low level once they have been reduced by other methods.

Ultrasound and electromagnetic devices: The sense of hearing among rodents is above 20kHz thus extending well into ultrasonic range. Ultrasound devices are being used as deterrents to rodent immigration. However, no convincing evidence was found them as effective against rodents. Similarly, little scientific support was found for use of electromagnetic devices.

Biological control using rodent predators: Snakes and owls have been the natural predators for field rodents. Bird perches are used for attracting owl perching in the nights to facilitate hunting the colonising rats. The perches should be used at tillering stage of the crops to tackling immigrating rodents. However, if these perches are continued in later stages, granivorous birds may cause damage to the panicles. Since most of the predators of rodents are general feeders, they often tend to feed on food other than rodents. Cats in residential premises are one of the examples. Declined rodent population after harvest of the crops also makes the predators to leave the area. There is also sometimes a possibility of predation triggering increase in rodent populations after partial removal of the rodents. Attempts were also made with parasites and pathogens to bring successful rodent control. However, the efforts are so far not fruitful since they also equally affect human populations. Attempts are in progress to use immuno contraception through viral vectors (VVIC) among rodents. However, the trials are at infancy stage only.

Botanical/ Chemical repellents: There is no effective chemical repellent available that is not also toxic. Although pheromones appear to be promising, lot of scientific work is required to identify, isolate and bring out the pheromones for extension purpose. Botanical based repellents are also available under different trade names (EcodonR -Castor based repellent, Bio-repel etc.) for use as field/ bund sprays.

PREVENTIVE RODENT PEST MANAGEMENT

Apart from the above non-chemical rodent management techniques, preventive rodent control generally practiced in residential premises and storage godowns can be explored without using any chemicals or devices simply by following the 4-D formulae (Deny entry, Deny shelter, Deny food and water and Destroy). Success of any preventive measure in residential or storage facility mainly depends on thorough inspection/ survey of the premises.

Inspection of the residential premises for rodent infestation is to be performed as a first step. The procedure of the inspection is as follows:

1. Observe the following around the premises and mark them on the layout of the area.

- Rodent burrows
- Drainage canals
- Holes at the base of compound wall
- Garbage dumps

2. Observe the following on the building/premises and mark them:

- Branches of trees overhung on the premises
- Wires from poles to the premises
- Holes in the walls
- Drainage pipes

3. Observe for rodent "signs" inside the premises, room wise and mark them.

- Faecal pellets adjoining walls or corners
- Rat holes, if any, active/inactive
- Rat/mouse paw markings
- Rat runways
- Rat smears on beams, wiring etc.
- Base of the doors for space
- Windows/ventilators connecting any wiring or on roof
- Drainage

Special care should be taken while inspecting storage areas. Based on the layout marked the following actions may be initiated based on the severity/intensity of the problem.

Rodents require food and shelter for their survival in crop fields or in storage. If any of these two factors are altered or eliminated, they will leave the place. An effective method of reducing rodent damage is rodent proof construction. It is less expensive to design a rodent proof building than to add rodent proofing later. Following measure may be taken for an effective rodent management:

☞ To prevent rodent entry through holes and openings close the hole with (a) concrete of 2 inches thickness (b) fitting galvanised sheet metal of 24 gauge (c)fitting perforated metal sheet grills of 14 gauge(d) 9.5 cm thick bricks with joints filled with cement mortar (e)wire mesh fitting of 24 gauge with 6.35x6.35 mesh and (f)fixing of aluminium frame of 22 gauge or aluminium guard of 18 gauge. Fix wire meshes (24 gauge) to all windows, ventilators, gutters and drains

☞ To prevent rodent entry through ventilators and windows fix galvanised wire mesh of 1.3 x 1.3 cm with cross bar support if necessary.

☞ Door should fit tightly with the distance between the bottom of the door and the floor not exceeding 0.6 cm. Fix 25 cm. metal sheet lining or rubber sheet at the bottom of the doors.

☞ To prevent entry into buildings through foundations, extend foundation wall below ground at least 91 cm

☞ To prevent entry into poultry sheds or godowns through floor instead floors, slabs with curtain walls of concrete of 0.6 cm with mesh wire (Ferro-cementing technique).

☞ Fix metal guards on drains and pipes to prevent their entry to the buildings. Flat guards may be used to prevent rodents form travelling along horizontal or vertical pipes. Cones or discs may be used for suspended cables, pipes etc

☞ Close the rodent burrows with concrete and cement.

☞ Remove the branches of the trees over hung on the godowns.

☞ Maintaining proper hygiene and sanitation will automatically reduce the rodent infestation from the premises.

RODENTICIDES IN RODENT PEST MANAGEMENT

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INTRODUCTION

Rodents have always with us, mostly as pests, ever since the primitive man took agriculture and started granaries. With the development of green revolution, technology of crop production along with protection revolutionized the Indian agriculture from a natural subsistence type to a well-managed intensive agriculture. However, with increased production and productivity, the problem of pests and disease also increased manifold. Among the pests, rodents, an important vertebrate pest take a heavy toll of our crop produce at every stage of crop production, processing and storage. On a very conservative estimate rodents cause 5-15% loss to our food basket. The problem of rodents is on rise in recent years due to globalization and climate variability providing highly favorable environmental conditions for rodents. Besides direct damage to standing crops and stored commodities, many rodent species acts as vectors of several zoonotic diseases of man and his live stock. Therefore, it is necessary to manage the rodent pests effectively for our food and health security. Use of rodenticides is one of the best tools for rodent control. It is often recognized that rodent control is one of the oldest pest control practices in the world. The earliest form of chemical pest control was probably through use of arsenic compounds in rodenticide formulations.

Rodenticides means rodent killing substance, may be of plant or chemical origin. Poisoning or chemical control is the most common, expedient and humane method of to control rodent depredations. As a principle the rodenticide should have three ideal attributes i.e., toxicity, acceptability and safety in use.

TYPES OF RODENTICIDES

Rodenticides may classify on the basis of the mode of action, origin/chemistry, and mode of entry in the target animals

1. Based on mode of action: On the basis of mode of action the rodenticides are usually classified as (i) Acute rodenticides which show quick toxic effects on the target pests in a single dose and (ii) Chronic rodenticides, which are slow acting and mostly require multiple dose for effective mortality. This dichotomous classification is based pon their mode of action rather than chemical structure or physiological action. The acute rodenticides include zinc phosphide, Barium carbonate, Arsenic trioxide, nor-bromide, sodium monofluoro acetae and strychnine alkaloid, redsquill, etc. Likewise, chronic rodenticides, which are mainly anticoagulants, include warfarin, coumatertlyl, diphacinone, bromadiolone etc. The anticoagulants are further grouped as first generation anticoagulants i.e., multi dose rodenticide, like warfarin and (ii) single dose rodenticide like bromadiolone.

2. Based on Origin/ Chemistry: The rodenticides may be of plant origin or chemicals.

i) Plant origin rodenticides: These are the oldes rodenticides being used since 17-18th century. This group includes two products (i) Strychnine: active ingredient is an alkaloid extracted from seeds of Strychnos nuxvomica. (ii) Red squill: Its biological product is extracted from the fleshy bulbs of red mediterrannean sqill, Urginea maritime. Strychnine alkaloids is a poison with very rapid action causing death by paralysis of central nervous system. However, poisoning with Red squill results into heart failure followed by paralysis. None of these compounds are registered in India.

ii) Chemical origin rodenticides: Rodenticides of chemical origin may be (i) Inorganic: for example, Zinc phosphide, Barium carbonate, Aluminium phosphide, Arsenic trioxide, Thallium sulphate etc and (ii) Organic: Alphanapthyl Thiourea (ANTU), Norbromide, cholcalciferol, anticoagulant rodenticides like Warfarin, Bromadiolone etc.

3. Based on mode of entry: The rodenticides enter in the body either orally (in form of baits) or through respiration (fumigants) therefore grouped s stomach or respiratory poisons. The concept of rodent control through rodenticides is based on baiting. The poison baits provide excellent success because “rodents cannot vomit” and once lethal dose is consumed, it cannot be thrown out, therefore chemical acts at the desired site (stomach) and yields effective mortality. While using acute rodenticidal baits, it is necessary to undertake pre baiting which acclimatizes the target pests to new food leading to enhanced intake of poison baits. The baiting with chronic rodenticides, which also enters orally and acts chronically on circulatory system, do not require pre-baiting. Aluminium phosphide a, burrow fumigant is the only respiratory rodenticide registered in India.

RODENTICIDES REGISTERED IN INDIA

The Central Insecticide Board and Registration Committee under Directorate of Plant Protection Quarantine and Storage, Ministry of Agriculture and Farmers Welfare, Govt of India is the only regulatory authority for registration of pesticides for use in the country. As per the provisions of Central Insecticide Act (1968) only seven rodenticides are registered. They include acute rodenticides like, (i) Zinc phosphide (ii) Aluminium phosphide (iii) Barium carbonate and chronic rodenticides like (iv) Warfarin (v) Coumachlor (vi) Coumatetralyl and (vii) Bromadiolone. Although seven molecules are registerd in the country only zinc phosphide (acute) and

Bromadiolone (Chronic/anticoagulant) are commonly available presently. The fumigant, aluminium phosphide (56% a.i 3g tablet), which is basically used as grain protectant was also earlier recommended for burrow fumigation. However due to its high toxicity it has been kept under restricted ban. Recently a new formulation of aluminum phosphide (6% a.i., 12g tablet) has been registered for rodent burrow fumigation.

A. ACUTE RODENTICIDES

1. Zinc phosphide

Zinc phosphide (Zn_3P_2) with IUPAC name Tri Zinc Di Phosphide is the most commonly use rodenticide in the world. It was first used in 1911-12 against vole outbreak in Italy but gained popularity in 1930 is still the most popular acute rodenticides available today. The rodenticide was registered in US in 1947 whereas, in India it was deemed registered by CIB & RC under the category 1 'Extremely toxic'. It is produced by direct combination of zinc with phosphorous. It comes in greyish black powder form having garlic like odour. The compound is insoluble in water and alcohol, stable when dry and decomposes gradually in moist air. Its route of exposure is through contact (dermal and ocular) and oral ingestion.

i) Dosage: Zinc phosphide is used in baits from 1 -5 % concentration, however it is recommended for use at 2.0-2.5% in cereal baits, because beyond this limit the bait acceptability is reduced and possibility of development of shyness behavior increases.

ii) Mode of action: Zinc phosphide is given in the form of baits, which are quite stable in air or non–acidic media, but when ingested, the acids present in the stomach releases the lethal phosphine gas:

$$Zn_3P_2+6HC1 \longrightarrow 2PH_3+3ZnCl_2$$

The animals ingesting lethal amounts of baits usually succumb overnight with terminal symptoms of convulsions, paralysis, coma and death. Release of phosphine gas produces necrotic symptoms and kidney is damaged causing death of the animal due to heart- failure.

iii) Toxicity: Depending upon the intake of zinc phosphide bait death of rodents occurs within 2 hours to 2-3 days. It is effective against a wide range of rodent specirs as evident from LD50 values (Table 1). Zn3P2 is equally toxic to man and other non- targets. Its LD 50 for chickens is as low as 7-10 mg/kg. Utmost care is needed while preparing and applying poison baits. The dead rodents must be properly disposed, by burying them deep in soil.

Table 1. LD 50 values of Zinc phosphide for major rodent pest species

SN	Species	Approximate LD50 (mg/kg)
1	Indian gerbil, *Tatera indica*	35.00
2	Indian desert gerbil, *Meriones hurrianae*	35.00
3	House rat, *Rattus rattus*	40.50
4	Soft furred field rat, *Millardia meltada*	82.00
5	House mouse *Mus musculus*	250.0
6	Lesser bandicoot rat *Bandicota bengalensis*	25.00

iv) Application techniques: Zinc phosphide is recommended to be used at 2-2.5% concentration (W/W basis) in cereal baits. Bait Preparation: It is an important aspect of rodenticide application technique, which is often overlooked. The proportion of toxicant to bait should be maintained properly. More over Being an acute rodenticide zinc phosphide baiting cannot be resorted very frequently as it induces bait shyness/ poison aversion among the survivors who had consumed sub lethal doses. Therefore, efforts should be made to cover maximum possible area in one go so that majority of population consumes lethal doses through poison baits. Therefore, besides selecting most preferred cereal bait, it is mandatory to go for pre- baiting (baits without poison). Pre baiting acclimatizes the field rodents for new food material, thus when poison baiting is done after 2-3 days of pre baiting, the native rodents get used to the new food and consume the poison bait in sufficient quantities leading to effective kill to the tune of 60-70%.

The baiting technology developed by AINP-VPM is very simple, economic, effective and widely accepted by the farming community. It requires only three components i.e., cereal, edible oil and zinc phosphide. The method is explained below for preparing one Kg bait.

Pre-bait material: for one Kg of pre bait bait.

- Take 960g of locally grown food grains (broken rice/ wheat/bajra /ragi/jowar).
- Mix 20g vegetable oil in food grain with bare hands.
- Apply in live burrows (@15-20g/burrow) or bait stations (@ 40-50g/station)

Poison bait material: for one Kg bait

- Take 940g of locally grown food grains (broken rice/ wheat/bajra /ragi/jowar).
- Mix 20g vegetable oil in food grain with bare hands.
- Sprinkle 20-25 g of zinc phosphide and stir with wooden stick till uniform mixing is achieved. (No house hold utensil be used for this purpose).

- Use any plant leaf as applicator for bait placement inside the burrows or the baits can be placed deep in the burrows in paper packets.

v) Limitations in use of zinc phosphide: As mentioned earlier, sub lethal intake of zinc phosphide induces bait shyness and poison aversion in target pets. In fact, zinc phosphide bait yields almost 60-70% control success in one go. The survivors (30-40%) comprised of rodent pests who either escaped the baits or consumed sub-lethal dosages, therefore do not die. The sublethal intake of poison induces shyness, with the result zinc phosphide baits cannot be used very frequently. This conditioned aversion behavior persists for a month in *B. bengalensis* to 135 days in M. meltada (Table 2).

Table 2. Persistence of zinc phosphide induced bait shyness among Indian rodents

SNo	Rodent species	Persistence of bait shyness (days)
1	Five stripped squirrel, *Funambulus pennanti*	30
2	Lesser bandicoot rat, *Bandicota bengalensis*	30
3	Indian gerbil, *Tatera indica*	115
4	Indian desert gerbil, *Meriones hurrianae*	35
5	Soft furred field rat, *Millardia meltada*	135
6	Indian field mouse *Mus booduga*	95
7	House rat, *Rattus rattus*	75
8	House mouse *Mus musculus*	20

2. Barium carbonate (Ba CO3)

Barium carbonate is also quite old rodenticides which was first used in 19th century against field mice out-break in Germany. Later on, it lost its ground as popular rodenticides during First World War. It is white crystalline solid almost inscrutable in water but reacts with acid to produce Barium chloride.

i) Toxicity: It has low toxicity for rodents and high toxicity for human beings, livestock, birds and cats. It gives very erratic results and the acceptability of the bait is also very poor. Its LD50 for B bengalensis is 446 mg/ kg and for R. rattus it is 975 mg/kg.

ii) Mode of action: The compound, with the help of acids present in the stomach reacts and carbonate is converted into chloride which is absorbed in body system and causes toxic effects. The symptoms of poisoning also include strong diarrhea and diuresis. Death is caused due to the contributing factors like, depression of brain causing respiratory failure, circulatory depression due to the action of the heart and shocks associated with strong purgative action.

iii) Dosage: Barium carbonate is generally used at 10-20% conc. in bait. It has been observed that Ba CO3 containing baits are less effective if they contain high proteins. Secondly this poison gives very erratic result in fields and thirdly it is more toxic to non- target species including man. All these drawbacks account for its least popularity as a rodenticide. Though it is a registered rodenticide but is not being manufactured now.

3. Aluminium phosphide

Aluminum phosphide, a respiratory poison is a used as burrow fumigation for rodent control. Earlier, this fumigant with a.i. 56% in form of 3g tablet (mainly recommended as grain protectant) was recommended (1.5g/ burrow) for rodent burrow fumigation also. Because of being highly toxic, this is under restricted ban. Keeping in view of its possible hazards, pellet formulation (0.6g) at a.i.56% was also brought out for rodent control as burrow fumigant (2 2pellets/ burrow). Besides, aluminium phosphide (56%) the formulation also contained ammonium carbonate, aluminium oxide wax, (44%). Recently a new formulation with reduced a.i. of only 6% in form of 12g tablet has been registered. Considering the safety aspects, the new formulation also contains bitterents and emetic substances.

i) Mode of action: Aluminum phosphide on exposure to the moisture evolves a non-inflammable gaseous mixture of phosphine, ammonia and carbon dioxide. The lethal gas is phosphine. The route of entry to the rodents is through respiratory system. The mode of action of the poison in the body system is similar to that of zinc phosphide as in the both the cases phosphine is the killing agent and the animal dies of kindly, liver injury, heart failure and paralysis. When applied in the burrows the lethal concentration of the gas is built up very quickly and persists for a considerable duration. The sped of liberation of the gas in the burrows is dependent on both soil moisture and temperature.

ii) Toxicity: It is also a highly toxic compound against a wide range of animals. Death occurs within few of hours of intake of phosphine. The decomposition of aluminum phosphide is faster in humid condition. However, at least 45 minutes to 1 hour is required for decomposition to start.

iii) Application: Aluminium phosphide is generally recommended for field use, in case of either severe infestation or as a follow up measure after zinc phosphide baiting for managing the residual rodent populations. One 12g tablet is to be inserted deep inside the burrows with the help of applicator and then burrows are to be plugged with wet mud so that the phosphine gas relaesed from the tablets do not come out and spread inside the burrow system. Aluminium phosphide has certain advantages, over poison baiting. Because it is quite effective and easy handling and does not involve any bait material, the action is fast, least hazardous to other grazing animals and no risk of bait shyness. Moreover, because of being respiratory poison the burrow inhabitants of all age groups i.e adults as well as the suckling litters are killed inside, whereas the poison baiting technology kills only the adults.

B. CHRONIC RODENTICIDES

1. Historical perspectives: The chronic rodenticides at present include only anti-coagulants. These poisons interferer with the coagulating mechanisms and inhibit the coagulation process. Anticoagulant were accidentally discovered, when large number of cattle died due to extensive hemorrhagic conditions after feeding spoiled sweet clover hay in USA. The compound responsible for death of cattle was identified to be dicoumarin. Workers at Wisconsin Alumini Research Foundation were responsible for isolation of dicoumarin and also for synthesis of several analogues in an effort to increase the potency of the parent compound. The 42nd member of the series, subsequently called as Warfarin (derived from Wisconsin Alumini Research Foundation or WARF) proved to be most active.

Early interest in anticoagulants was mainly concentrated on its therapeutic use for treatment of thrombosis. The rodenticidal potential of such compounds were independently recognized in USA and UK during 1946-48 Because of greater potency warfarin superseded dicoumarin and very soon became the dominant rodenticide. Thus, dicoumarin was introduced as a commercial rodenticide in UK in 1949 nad warfarin was registered in USA in 1950. Chemically the anticoagulants are classified in two groups i.e., (i) Hydro coumarines e.g. warfarin, Coumachlor, Diaphaciane, Chlorophacinone, Pindone etc and (ii) Indane diones Coumachlor, Coumatetralyl, Coumafuryl etc

2. Mode of action: As the name anticoagulant these rodenticides, though fed as baits are stored in liver and act on blood vascular system. Development of anticoagulants was highly significant as they overcome nearly all the negative aspects of acute rodenticides. The mode of action on the physiology of target animals is almost some for all the anti-coagulants.

They competitively interfere with vitamin K1 in the liver. Vitamin K1 is an essential factor in the synthesis of four dotting proteins which are essential for formation of thrombin in the blood coagulation mechanism. The molecular structure of Vitamin K1 and anticoagulants are similar, they block the epoxide reductase enzyme therefore stopping the recycling of activated Vitamin K1. Leading to accumulation of Vitamin K1 oxide. As a competitive antagonist of Vitamin K1, the anticoagulants replace the former from the system and therefore formation of prothrombin (necessary for blood clotting) is hampered. Due to failure of this mechanism the internal bleeding occurs in organs and tissues that ultimately leads to death of target animals. The process is explained as below;

Normal

- In process of biochemical chain reaction prothrombin present in blood is converted to Thrombin.
- Thrombin causes interlacing of dissolved fibrinogen into more firmly structured fibrin. The wound is closed.

Poisoned with anticoagulant

- Prothrombin is produced in the liver from a chemical precursor. Vitamin K 1 is indirectly involved in this process
- The anticoagulants and Vitamin K1are similar in structure, therefore capable of displacing Vitamin K1 from its action site. So, prothrombin synthesis is interrupted.
- Prothrombin concentration in blood declines. Fibrinogen cannot be converted in fibrin. Blood loses its capability to coagulate.
- In addition, capillary walls become fragile -internal bleeding - rodent dies of anemia.

3. Two generations of anticoagulants: Development of anticoagulants has passed through two generations. The first-generation anticoagulants were multi dose in requirement as the poison bait was to be fed to target animals for longer periods (7-15 days) for effective kill. The first-generation anticoagulants, principally hydroxy-coumarines included warfarin (1949-50), coumachlor (1951), coumatetralyl (1956) and indane diones, that included difecinone (1952) and chlorophacinone (1961), etc. During 1970s a new generation of anticoagulants were discovered which are required as single dose, i.e., effective kill is achieved even at single dose feeding. The discovery of such chemicals has provided a conceptual breakthrough in the areas of rodent control, because they are effective in single dose but are devoid of all negative points of acute poisons. Difencoum and brodifacoum, bromadiolone were the earliest commercially available rodenticides (1975-78) of the second generation in Europe (not in India). In later years flocoumafen and difethiolone were also added. Of these only bromadiolone is registered and commercially available in India. Both generations being chronic poisons results in delayed mortality of target animals. The chemicals are slow in action on target species and are to be fed to the animals for several days for effective kill.

First generation anticoagulants

1. Warfarin: As stated above warfarin belongs to first generation anticoagulant and is registered in India. It is based on hudroxy-coumarin compounds and is categorized as muti-dose rodenticide.

Warfarin had a wide scale use in commensa rodent management in Western Countries, but its use is at decline with the evolution of single dose anticoagulants. The LD50 valves of warfarin against *Tatera india*, *Meriones hurrianae* and *Mus booduga* are 4x19.1 and 4x15.9, 4x15.9 and 4x28.3 mg/kg respectively. Warfarin is generally recommended at 0.025 percent dosage in baits and requires at least 7-14 days feeding to bring about 100% mortality of various rodent species. *Bandicota bengalensis* succumbed at least after 10 days feeding on warfarin baits @0.025% conc. One of the field trials indicated that 7-10 days baiting with warfarin (0.025%) resulted into 66-100% rodent control success. Warfarin dominated the practice of rodent control during 195—1965 world over. These were used to such sacle that perhaps led to development of resistance in rodents. First case of resistance was reported in UK in 1960 against *Rattus norvegicaus* and later in *Mus musculus* and *Rattus rattus* also from many European countries and USA. Even cross resistance was also reported in many cases. In India no resistance as such was reported. Some workers observed warfarin tolerance in *Bandicota bengalensis* and *Rattus rattus*. Problem of developing resistance and cross resistance couple with difficulties in multiple baiting for several days led to the decline of warfarin use in rodent control all over the world. Though registered in India also, it is not available presently.

2. Coumachlor: Coumachlor is another first-generation anticoagulant rodenticide registered in India, but could not become popular for rodent control, because of similar reasons as mentioned with warfarin (multi dose requirements and chances of development of resistance) and therefore not available now. Studies have shown that coumachlor at 0.025 and 0.05% in baits could yield 30-80% kill of *Rattus norvegicus* after 3-5 days feeding and 70 kills in *Rattus rattus* after 7 days feeding. Acute oral toxicity of choumachlor is 900-1200mg/kg for rats but repeated administration for 14 days at a rate of of 0.1-1 mg/kg.

3**. Coumatetralyl:** Coumatetralyl has been used for commensal control in many countries. It is formulated as a dry bait (0.0375%), a liquid bait of its sodium-salt, and a 0.75% tracking powder.

Pure coumatetralyl is a colorless and, odourless white crystalline powder. The acute and chronic LD50 to *R. norvegicus* are 16.5 and 0.3 mg/kg for five consecutive doses, respectively. Chickens are quite resistant to coumatetralyl, with a chronic LD50 of 50 mg/kg for eight consecutive doses. In spite of its low toxicity, coumatetralyl is reported to be a little more effective than warfarin against rodents, apparently due to a higher palatability. Coumatetralyl was introduced after the detection of warfarin-resistant rat populations, and showed considerable success for a number of years, but resistant pests have been reported in the United Kingdom and Denmark. LD 50 values of coumatetralyl against Indian rodents was 4x 0.60 and 4x0.53 mg/kg against *T. indica* and *M. hurrianae* respectively. For rats, the acute toxicity LD 50 is 13.5 mg/kg and chronic toxicity LD50 for rats is 0.3 mg/kg daily for 5 days. For registration it is categorized as extremely toxic. Like other anticoagulants its mode of action is similar. i.e, acting on blood vascular system by inhibiting the blood coagulation process. It was reported that coumatetralyl was relatively more toxic to *B. bengalenesis* as 100 % kill was noticed even in one day feeding with a death period of 4-7 days (Table 3). Tracking powder formulations (0.75% a.i.) are registered in India. The powder can be directly used as tracking powder or mixed in bait (at 0.0375%).

Table 3. Bio-efficacy of Coumatetralyl against Indian rodents (no choice)

SN	Rodent species	Conc. (%)	Feeding period	Mortality
1	*Bandicota bengalensis*	0.0375	1	100
2	*Tatera indica*	0.0375	3	80
		0.0375	5	100
2	*Meriones huurianae*	0.0375	5	70
		0.05	7	100
3	*Rattus rattus*	0.025	15	100
		0.0375	7	100

i) Tracking powder: Use of coumatetralyl tracking powder is based on the typical rodent behavior. Rodents generally spend almost 20% of their activity period in cleaning and grooming their fur. When the powder (a.i. 0.75%) is applied in thin films on the rodent runways, the poison powder gets stuck on their furs. While cleaning and grooming the rodents ingest the lethal dosages and dies.

ii) Baiting: The recoomended dose of coumatetralyl for rodent control is 0.0375% in baits. The same tracking powder with an a.i. of 0.75% can be diluted to this concentration by mixing the powder in cereal baits. For example, to prepare 1 kg of coumatetraly baits, take 930g of any cereal (broken wheat/ rice/ jowar/ pearl millet/ ragi etc and smear it with 20g of any edible oil. Add 50 g of coumatetralyl tracking powder (a.i. 0.75%) and mix it thoroughly so that powder gets uniformly adhered on the oil smeared grains. The baits can be directly applied in the burrows or through bait stations.

Second generation anticoagulants

Second generation anticoagulants are single dose anticoagulants with similar mode of action. In fact, these were synthesized by substituting stereochemically similar side chains into 4- hydroxyl coumarine moity, which were effective against resistant strains and considferably more potent than then first-generation anticoagulants. Initially two compounds difencoum and brodifacoum were selected and were the first commercially available second-generation anticoagulants in UK in 1975 and 1978 respectively. Meanwhile bromadiolone another compound of the same generation was developed in France. Later on, two more compounds, viz., flocoumafen and difethialone were developed and commercialized in western countries. Among these bromadiolone, brodifacoum, flocoumafen and difethialone were extensively evaluated against rodent pests in laboratory and fields in India and all have shown their potency against Indian rodent species. The LD50 values o the two common second generation anticoagulant rodenticides, Bromadiolone and brodifacoum indicates their high toxicity for Indian rodents as well (Table 3). The single dose toxicity of these anticoagulants against Indian rodents are depicted in Table 4.

Table 3. LD 50 values of Bromadiolone and Brodifacoum for Indian rodents

SN	Rodent species	Bromadiolone (mg/kg)	Brodifacoum (mg/kg)
1	*Tatera indica*	0.11	-
2	*Meriones hurrianae*	0.55	0.083
3	*Bandicota bengalensis*	1.58	-
4	*Mus booduga*	0.37	0.31
5	*Millardia meltada*	-	0.66
6	*Rattus rattus*	1.00	0.77
7	*Mus musculus*	-	0.30

Compared to first generation anticoagulants, these are more toxic and effective at a very lower concentrations in baits (0.0025% for difethiolone and 0.005% for others) at single application. These are also effective against warfarin resistant and zinc phosphide induced bait shy rodents. Generally, the toxic effect of these chemicals starts from 3rd day of bait intake and continues for 10-12 days for effective kill of pest rodents. Besides their smaller requirements in baits in a single dose and availability of an effective anti-dote (Vitamin K1), the second-generation anticoagulants have an edge over other rodenticides not only in efficacy but in safety also. Presently only bromadiolone (0.005%) is registered by Government of India for rodent control in fields and commensal situations.

Table 4. Single dose toxicity of grain baits of second-generation anticoagulant rodenticides

Rodent species	Per cent mortality and (mean days to death) with			
	Bromadiolone (0.005%)	**Brodifacoum (0.005%)**	**Flocoumafen (0.005%)**	**Difethialone (0.0025%)**
Bandicota bengalensis	100	100 (6.6)	100	100 (5.8)
Tatera indica	100 (9.5)	90 (6.9)	90 (8.2)	100 (7.9)
Millardia meltada	100 (6.4)	80-100 (6.6-7.1)	100 (5.7)	100
Meriones hurrianae	88	83-100 (4.7-8.0)	100 (7.0)	100 (5.9)
Rattus rattus	100 (7.5)	83-100 (8.0-10.8)	100 (8.6))	100 (5.9)
Mus musculus	91 (8.1)	60-100 (4.6-8.4)	100 (6.8)	-
Mus booduga	83	83 (9.4)	-	-

1. Bromadiolone: Among the second-generation anticoagulants evaluated in India, only bromadiolone is registered by Central Insecticide Board and Registration Committee since 1988. It is recommended at 0.005% concentration in baits and is commercially available is in two formulations (i) ready to use wax block baits and (ii) Concentrate Bait (CB) with 0.25% a.i. The end users can prepare fresh baits of desired concentration (0.005%) with CB formulation. It is being extensively used throughout the country and has provided over 80% rodent control success. Bromadiolone (0.005%) is recommended for burrow baiting/ station baiting in all crops either directly or as a follow up after one treatment with acute zinc phosphide for managing bait shy populations. Bromadiolone is equally effective against field and commensal rodents and therefore are recommended in both situations at 0.005% in baits.

Application: The ready to use available at recommenced concentrations (0.005%) in wax blocks can directly be used in burrows (10-15g/burrow) or bait stations. The wax blocks can directly be placed in coconut crown for managing rodent problem in coconut. Farmers can prepare fresh baits with locally available cereals and other additives by using bait concentrate powder. The techniques of bait preparation of bromadiolne is similar to that of zinc phosphide. For preparing 1 Kg of bromadiolone bait smear the cereal bait (960g) with any edible oil (20g) and mix 20g of bait concentrate powder (0.25%) to achieve the recommended dose of 0.005%. This can be used in the rodent burrows in fields or in bait stations in commensal or even field situations.

ADVANTAGES OF ANTICOAGULANT RODENTICIDES

Prior to discovery of anticoagulants, the rodent control mainly depended upon acute rodenticide, like zinc phosphide. The only fault with acute rodenticide is that it produces symptom of poisoning very rapidly. Rodent behavior is such that when they encounter any new food, they simply sample a small quantity and may not take substantial quantity. If the bait causes distressing symptoms during sample feeding, rodents are intelligent enough to recognize the cause and effect and therefore avoid such feed leading to poison aversion or bait shyness. That is why pre-baiting is recommended before baiting with acute rodenticides, to significantly reduce this effect, still a good number of rodents in population develop shyness. In case of anticoagulants the delay between ingestion of potentially lethal doses of poisoned baits and appearance of symptoms is such that rodents are not able to recognize their relationship and thus there is no issue of bait shyness with anticoagulants. More over the death with such poisons are relatively painless also. Thus, major advantage with anticoagulants is that bait shyness does not occur and there is no need of pre baiting.

In case of accidental poisoning, time between ingestion and appearance of symptoms of poisoning (because of slower mode of action) there is always sufficient time proper medical treatments. More over Vitamin K1 may be administered which is a very potent antidote for the anticogaulants.

Anticoagulants are required in very small doses as compared to acute poisons. For example, bromadilone is recommended 0.005% in baits whereas acute zinc phosphide is recommended at 2-2.5% in baits.

A comparison of acute and chronic (anticoagulants) is presented in Table 5.

Table 5. Acute and anticagulant rodenticides: A comparison

S. No	Actue rodenticides	Anticoagulant rodenticides
1	Quick action on target animals	Delayed action, thus death occurs slowly.
2	Dead rodents are seen soon after the control operation.	Dead rodents are not seen in large numbers.
3	Induce poison aversion and bait shyness behavior	No such problem.
4	Require probating, which is a major constraint in successful control operation.	No probating is required
5	Effective where anticoagulant	First generation compounds had

	résistance is a problem	problems of resistance development not reported so far with second generation compound.
6	Poison and bait are required in small amounts	First generation anticoagulants are required in large quantities in bait but not so with second generation anti- coagulants.
7	Highly toxic to non- target species, i.e, poor selectivity	Comparatively safer.
8	High concentrations required which can lead to un palatability	Palatable because of low concentration requirement
9	No effective antidote available. More over the time between ingestion and symptoms is very short to provide medical help.	VitaminK1 is an effective and practical antidote.

PRECAUTION IN HANDELLING RODENTICIDES

- All rodenticides (pure chemicals, baits etc.) should be clearly labeled 'POISON' and be kept away from the reach of children prefearbly in a locked almirah.
- Poison baits should be prepared in well-ventilated room and care should be taken not to breathe in or absorb any poison.
- No eating, drinking or smoking should take place while preparing or handling rat poisons or poison baits.
- The person handling the poison baits should not have any cuts and abrasions on the hands and arms. Gloves may be used for additional safety.
- The poison bait should not be touched by bare hands. Use gloves and a small stick for mixing the baits and any broad leaf or spoon should be used.
- After poison bait preparation and field application, hands should be washed with soap properly.
- While placing the baits in the burrow, the poison bait should be rolled deep in the burrows to protect birds, livestock and other non-target species. Preferably bait stations should be used for planning the poison baits.
- When poison baits are laid, everybody in the area should be cautioned about the treatment so that children, livestock and pets can be kept away during the treatment period.
- After the control operations, the leftover baits, should be picked up and buried deep in the soil.
- Poison bait should not be laid where the excess bait cannot be picked up in order to prevent any later danger. A record should be kept of the number and location of baiting points.

- The treated area should be inspected regularly even 15-20 days after the poison baiting. All the dead rats must be collected and buried deep in the soil.
- In case of accidental intake of poison/ poison baits, provide first aid and report to doctor immediately.

FIRST AID AND ANTI DOTES

1. Zinc phosphide

First Aid: Call physician immediately. A table spoon of salt in a glass of water be given and repeated till vomiting fluid is clear. The victim should lie down and remove contamination from skin, eyes etc by copious flushing with water at least for 15 minutes.

Antidote: Induce vomiting by giving 0. 2% copper sulphate solution which acts as an emetic and also produces insoluble cupric phosphide that can be removed by gastric lavage with potassium 5g of permanganate dissolved in a glass of water. It oxidases the phosphide into phosphates Give 25-30 g milk of Magnesia or beaten whites of 2-3 eggs may also be given. Later on, any purgative be given and call the doctor immediately.

2 Aluminium phosphide

As such there is no antidote for this poison. Therefore, consult physician immediately. As a first aid remove the victim from exposure and keep at rest. If the victim is unconscious, place in semi-prone recovery position or otherwise maintain the air way. If the victim is conscious but feels difficulty in breathing keep him in sitting position and give oxygen, if available. If breathing stops, immediately ventilate the victim artificially with mouth to mouth/nose or mechanically with oxygen.

3. Anticoagulant rodenticide (Bromadiolone)

First Aid: If the anticoagulant has been swallowed recently (with in few hours), then induce vomiting by tickling the back of throat with clean fingers. Get medical help as soon as possible.

Antidote: Administer Vitamin K1 to restore blood clotting after repeated determination of level of prothrombin. In severe cases, agnamphyton IM/IV @ 5-10g in adults nd 1-5g in children may be given.

CONCLUSION

Though many techniques like habitat manipulation, mechanical biological control methods arte available but, use of rodenticides in integration with these methods is required for sustainable management of pest rodents. The list of rodenticides registered in India include 7 compounds, but many of them, like barium carbonate, warfarin and coumachlor are outdated and therefore only three of them are practically available at present. The second-generation rodenticides which have a great future, only bromadiolone has found place for Indian farmers. Several other anticoagulant rodenticides of this generation have been found extremely effective against Indian rodents, needs to be registered in India also to avoid total dependency on one chemical. Likewise, some other non-anticoagulant rodenticides like cholecalciferol and bromathalin are registered for rodent control in many countries. Cholecalciferl is is a vitamin D3 based compound causes hypercalcemia (mobilization of calcium from the bone matrix to plasma) in rodents leading to their death in 3-4 days. Similarly, Bromethalin a nerve poison is a single-dose rodenticide and rodents die within 2-4 days after ingestion of lethal dose. These two compounds too have great scope in providing enough options to India framers in management of rodents n their crop fields and storage.

ROLE OF RODENT BEHAVIOUR IN RODENT MANAGEMENT

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Understanding of rodent behaviour is a vital for planning eradication of long-established rat populations in agricultural as well urban ecosystem. They have many ecological and behavioural adaptations which are given below:

HABITAT (Fossoriality)

They adapt to a wide range of habitats. Bandicoots are fossorial (live inside the burrow) they are good diggers. The borrows will be occur only in irrigated croplands the burrows having a scooped soil at the entrance with pebbles. Major channels and around village gardens are prime habitats during fallow. The squirrels are arboreal. They live in tree trunks and make nest. House rat in urban areas they are found around warehouses residential, buildings, and other human settlements. In cities their preferred habitats are in dry upper levels of buildings, so they are commonly found in hollow places in wall cavities and false ceilings. In the wild conditions they live in cliffs, rocks, the ground, and trees. *R. rattus* are excellent climbers and found in trees, such as pines and palm trees. Their nests are typically spherical and made of shredded material, including sticks, leaves, other vegetation, and cloth. The Norway rat lives in the underground. It is strong burrowing animal sometime the burrowing activity may lead to collapse the building. Porcupines make shelters in caves, rock crevices, dark holes, or dens / burrows, excavated by the species along the side of a hill / hillock or in the plains. These burrows will become expanded and enlarged as the rat population grows. Many burrows may interconnect with one another forming a complex network of underground tunnels. These burrows will contain one main entrance, as well as two bolt holes which are used for escape purposes. Constant environmental conditions will be maintained inside the burrows, facilitated by soil. The depth normally depends on the atmospheric temperature. It is essential to understand the spatial distribution of rats and their burrow for management of rodent populations.

- Porcupines – make crevices between rocky areas; the crevices are normally tapering; complex of crevices due to gregarious living.
- Bandicoots – scooped soil exists before the burrows with soil pebbles.

- Soft furred field rat – vertical burrow, which extends laterally
- Gerbils – the burrow is complex in nature, generally around a shrub or tree base

FOOD HABIT

Rodents like to live near water of any sort, and prefer foods rich in carbohydrates and protein. Rodents are omnivorous and can eat a wide range of plant and animal foods. Fruits, seeds and invertebrates are also included as a major portion in the diet. Larger bandicoot main food items are Invertebrates particularly insect larval, arthropods, reptiles, birds, and cockroaches. Unlike mice, rats cannot survive without open water requiring about an ounce of water daily. The physical capabilities of rats are extremely alarming. They can climb stairways, pipes, wires and even bare walls with a rough surface. Most rat populations are nocturnal operating between dusk and dawn. They will adjust, however, to feed during times which food is the freshest or most available.

NOCTURNALITY

They are crepuscular (Active mostly after dark), but are adaptable if warranted by circumstances; indoor mice are generally nocturnal but less predictable than rats. The spontaneous activity starts at evening hours after sunset and have exploration, feeding and feeding rhythms; the activity will be minimized by 9.30 pm. Again, they become active in early morning having exploratory and feeding activities.

EXPLORATION

Rodents have a habit of checking the environment during the spontaneous activity period. This is to guard the area where they live to check any incursions or change in the environment. This is an in born instinct of all rodents.

THEIGMOTAXIS

Prefer to travel along, and in contact with, vertical surfaces rather than in the open; wary of crossing open spaces that provide no cover. In field conditions they prepare to move side of the bund. Hence, the baits placed on the bund are not accepted. Territories of most of the rodents ranging from 50 to 150 feet from the burrow, however, rats will travel up to 300 feet to a food source. As rat populations grow, competition, conflict, and fighting begin to increase. Large males will become dominant and any given territory can be divided up into several social orders where subordinate males also maintain a smaller area. Many rats will often be seen during the day, as they must feed when larger dominant rats are inactive.

AGONISTIC BEHAVIOR

Agonistic behavior refers to the complex of aggression, appeasement and avoidance behavior that occurs between members of the same species. Agonistic behavior is a much broader term than "aggression," which refers to behavior patterns which serve to intimidate or damage another (for more, see McFarland, 1982).

SOCIAL AGONISTIC BEHAVIOR

Agonistic behavior involves several actions, or motor patterns, including chasing, sidling, boxing, biting, and kicking, as well as audible and ultrasonic vocalizations. Agonistic behavior can occur between rats in a colony, and between resident rats and intruders.

COMMUNICATION THROUGH URINE MARKING

Urine marking in rats refers to the deposit of drops or smears of urine in the environment, sometimes accompanied by secretions from preputial sebaceous glands (Birke 1978). Urine marking is a type of scent marking, a form of chemical communication, in which one rat, the sender, generates a chemical signal (the drop of urine) and transmits the signal by depositing the drop in the environment. Another rat, the receiver, identifies, integrates and responds (either behaviorally or physiologically) to the signal. It is assumed that the sender-receiver relationship is the result of natural selection, such that the sender's signal produces a response in the receiver that benefits the sender in some way (e.g. the signal attracts a mate for the sender etc.), while the receiver assesses the signal and responds in a way that most benefits the receiver (Agosta 1992). Urine marking is very common in mammals, and it has become adapted for use in a variety of contexts and may have more than one function in any given species. In addition, it may have different functions in different species (Johnson 1973). Chemical secretions contain an enormous amount of information (Agosta 1992). A rat who smells a urine mark can determine all sorts of things about the rat that produced it: its species, sex (Brown 1977), age (juvenile vs adult), reproductive status (Carr and Caul 1962), familiarity (Krames and Shaw 1973), social status (Krames et al. 1969), individual identity (Brown 1988, Carr et al. 1970), and current stress level (Mackay-Sim 1980, Giesecke 1997, Valenta and Rigby 1968). In addition, rats can tell how long in the past a urine mark was deposited.

NEOPHOBIA

Rats constantly explore their territories and are very wary of new foods, new objects, or changes in their environment. This behavior is known as neophobia and can last up to several weeks. This has definite impacts on the Control of Norway Rats. They exhibit bait shyness, often not returning to food which makes them sick after taking little nibbles in initial tasting. These are extreme neophobic rats which avoid all baits and traps. The neophobic response can be one of the most pertinent obstacles to efficient rat control (Lund 1988). Barnett (1958) defined neophobia as the avoidance of an unfamiliar object in a familiar place. It causes problems in poisoning programmes because neophobic animals will avoid new foods and even foods previously eaten if they are placed on or in a novel object (Barnett 1988). The response varies not only between species (see below) but also between populations of the same species (Mitchell et al. 1977) and between individual animals (Cowan & Barnett 1975).

Neophobic periods: *R. rattus* – 3 days; *B. bengalensis* – 1 day; *M. meltada* – 5 days; *T. Indica* – 3 days

BAIT SHYNESS

Aversion towards the poison bait is called bait shyness. A number of researchers, especially in India, have looked at the role of various food characteristics in the development of conditioned food aversions, and aversions to different poisons (e.g. Howard et al. 1968; Bhardwaj & Khan 1978; 1979a, b; 1980; Rao et al. 1980). Thomas & Taylor (2002) noted that either bait shyness or poison resistance was apparent in the rat population on Ulva Island. Cowan et al. (1994) recommended micro-encapsulation of poisons as a way of reducing the formation of learned aversions, by delaying the symptoms of poisoning. Sub lethal doses of acute rodenticide will not kill the rodents, but the minute quantities of phosphine generated in stomach will give stomach disturbance. Rodents will associate this discomfiture with bait material ate. Consequently, they avoid eating the food item- Bait Shyness. It is temporary phenomenon.

Persistent periods: *R. rattus* – 75 days; *B. bengalensis* – 21 days; *M. meltada* – 135 days; *T. Indica* – 75 days

RESISTANCE TO RODENTICIDES

Rats can also be physiologically resistant to poisons (Thijssen 1995; Taylor et al. 1996). This is a genetic trait that has been selected for over generations of exposure to certain rodenticides (Greaves 1994;). Warfarin-resistant mice, Norway rats and ship rats have been found in England and Europe (Boyle 1960). Warfarin resistant rats can be also resistant to difenacoum (Greaves et al. 1982). The issues of bait avoidance and the efficacy of poisons against warfarin- and difenacoum-resistant rats were discussed by Quy et al. (1992). Cleghorn & Griffiths (2002) found no evidence of resistance to brodifacoum in mice from Mokoia Island. Chronic rodenticides are reported to result in development of resistance over a period of time one more number of treatments. Bromadiolone has so far not shown proven anticoagulant resistance

MIGRALITY

Rodents inherently have migrality behavior - the movement in search of food sources. There are two types of migaration occur in rodents 1. Emigration – outward movement after the harvest in search of food available areas and 2. Immigration – inward movement of rodents to the crops under establishment. The range of movements depend largely on location between food resources and suitable harborage. Under stable conditions their movement is limited. Bandicoot the home range between 55 to 50 meters. A Norway rat will move within a diameter of 100 to 150 ft., a roof rat, 45 to 150 ft., and a house mouse, 10 to 30 ft. This range may expand when conditions are unstable or changes, such as a construction site. They may also expand their range in protected areas such as in sewers, in passages between buildings, and under groundcovers and during seasonal or climatic change

REPRODUCTIVE BEHAVIOUR

Reproduction plays a major role in the buildup of population densities since under normal conditions; it is the basic and most important source for recruitment. Changes in reproductive performance of a population will be reflected in density changes. A pair of adult rats will produce 6 young one (average litter size), sometimes they give with a maximum of 14 young one in favorable situation. One female can potentially produce 36 young in one cropping season. The male courting and mounting behaviour coincidental with ultrasound calling. It can be induced by female urine. Rodents have two types of reproductive behavior as summarized below

Normal Breeding (k-type)	**Abnormal breeding (r-type)**
Sex ration (M:F)- 1:1 Avg. Litter size – 6 Post partum oestrous- 90 days. Maturity period- 90 d This is seen in normal un-disturbed agrarian ecosystems	Sex ration (M:F)- 1:2 Avg. Litter size -20 Post partum oestrous- 2 days. Maturity period- 75 d This is seen during unexpected favourable climatic situations
	

1. Strategies for managing k-strategists: Where logistic growth occurs, i.e., situations of k-strategists, control measures must be sustained over the life of the crop that is protected. This is because the very existence of this type of growth indicates that conditions are continually favourable for the pest and must be regularly modified to make them unfavourable. Ideally, management aims to modify the carrying capacity of the environment for the rodent population to such a low level that the damage caused is economically insignificant. Biological control by introduced natural enemies is not likely to be successful since the densities of k-strategists are often too low to sustain a reliable predator population. This sort of pre-emptive intervention is less economically viable making it imperative to depend on chemical rodenticides. Even rodenticides are unlikely to be cost effective. This is because the shape of logistic growth curve with more than above 10% of their maximum numbers will quickly rebound to pest status. Indeed, the steepest part of the curve occurs at 50% of the asymptote and consequently, this is the target for reduction. Inappropriate rodent pest management can, therefore, produce more rodents, in total than no control effort at all.

2. Strategies for managing r-strategists: The management of irruptive or r-rodent populations requires a different strategy. Since damage is confined to times of outbreaks, sustained prophylactic control would be wasteful unless it cheaply forestalled irruptions viz., habitat manipulation. Therefore, the management of irruptive rodent pests focuses on prediction and monitoring of out breaks, with the tactical and prophylactic use of rodenticide to nip the outbreak in the bud and thereby preventing an outbreak. In some cases, cultivation timing can be altered so that the vulnerable crop stages coincide with periods when the possibilities for outbreaks of r-pests are minimal. Predators also react too slowly to prevent outbreaks of r-pests. Normally it is thought that mortality is the most critical population process to interfere within any control action. However, it is also a fact that increased mortality is often rapidly compensated by increased recruitment. Neglecting this fact leads to sustained yield. Many individuals are killed initially giving first impression of an apparent success. In reality however, the obtained reduction in population size is virtually absent. This is very commonly felt in most of the rodent control campaigns, which are not planned systematically looking at the situation of the pests, habitat and environmental interactions.

INTRINSIC POPULATION REGULATION

Many factors are responsible for the reproduction as it influenced mainly by pheromone communication. Here some of chemical communications responsible for reproduction control or population regulation they are, a) The Bruce effect, or pregnancy block, refers to the tendency for female rodents to terminate their pregnancies following exposure to the scent of an unfamiliar male. The effect has primarily been studied in laboratory mice

(*Mus musculus*), and also observed in deer-mice, meadow voles, and collared lemmings. The Bruce Effect has also been proposed, but not confirmed, in non-rodent species such as the lion. In mice, pregnancy can only be terminated prior to embryo implantation, but other species will interrupt even a late-term pregnancy. B) In Whitten effect, it refers to the male mouse pheromones will synchronize the estrous cycle of group housed females. C) In Vanderbergh effect, refers to exposure to male urine pheromones will induce earlier first estrus in pre-pubertal females.

POISON AVERSION AND BAIT SHYNESS IN RODENTS

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INTRODUCTION

The conducive climatic conditions for reproduction and population explosion, maintaining high population level in agriculture as well as in rural and urban situations. In India, 128 species of rodents belonging to 46 genera are present (Ellerman 1961, Roonwal 1987). Out of these, 18 species qualify as a pest. Some are localized pest and some of them are pest of National significance. They cause considerable direct damage to crops from sowing to harvesting in fields and storage and indirect damage by spoilage, contamination and hoarding duringon farm and post-harvest stages. The extent of damage and economic losses caused by rodents ranging from 2-15% persists throughout the country (Parshad, 1999). Rodents can transmit more than 60 diseases to humans and other animals. Being reservoir or vector of various dreaded diseases, they are also responsible for spreading diseases like Plague, Leptospirosis, Murine typhus etc. They are creating lots of health problems in human beings and domestic animals.

The most common, expedient and humane method to control the rodent depredation is poisoning or chemical control. The rodenticides are usually classified on basis of their mode of action rather than chemical or physiological action i.e. either as acute (single dose, quick action) or chronic (multiple doses, slow acting). Among the acute rodenticides, zinc phosphide is most commonly used in South Asia and forms the basis of 80–90% of rodent control operations, particularly in agricultural situations (Parshad, 1992). It is broad spectrum rodenticides with LD50 ranging from 25-40mg/kg in different species of Indian rodents. In baits, zinc phosphide is used from 0.75- 5.00 percent concentration, but it should not be ordinarily used at a concentration above 2 percent (Prakash, 1975), because beyond this limit the acceptability of bait is reduced and poison aversion increases (Bhardwaj and Prakash,1982). Extensive studies have been carried out on the problem of poison bait aversion in *T. indica* (Prakash and Jain, 1971), *M. hurrianae* (Prakash and Jain 1971), *G. gleadowi* (Rana et al., 1975), *R. rattus* (Bhardwaj and Khan 1978, 1979); *B. bengalensis* (Sridhara and Srihari 1978, Sridhara 1983, Parshad, 1989a,b, Parshad and Kochar, 1995), *M. musculus* (Rao and Prakash,1980) and *M. platythrix* (Sridhara and Srihari, 1980). Because of this problem rodents will continue to reject the zinc phosphide bait for 6–170 days. Repeated use of zinc phosphide, the aversion period may go upto 484 days, that is almost throughout their life in the case of *B. bengalensis* (Parshad and Kochar, 1995). Some times, farmers applied the zinc phosphide repeatedly at short intervals in the same field and this enhances aversive responses of rodents to poison baits and their control with zinc phosphide in such situations become extremely difficult. These studies are much practical importance from point of view of optimizing the control success (Prakash, 1974).

WHAT IS POISON SHYNESS OR POISON AVERSION AND BAIT SHYNESS?

Rodents have the ability to discriminate between harmful and harmless food through their highly developed olfactory sense and sampling behavior. They are not consuming whole food in a single bout. Both free living and captive rodents are likely to consume/eat only small sample of a new food at its first exposure. Many mammals avoid novel objects (Neophobic) whether it is poison bait, bait station or any other object in their familiar environment. The avoidance of poisons or poison baits after surviving of consuming of sub lethal dose of poisons, also termed as "Bait or poison shyness". It is conditioned food aversion, caused by associative learning are well documented in mammals ranging from rodents to primates (Garcia et. al.,1955; Roy and Brizzee, 1979). Rats respond to changes of the location where food appears, changes of the container in which the food is provided, as well as changes of the feed itself (Barnett, 2009; Caroll et. al., 1975; Cowan, 1977; Inglis et. al., 1996; Mitchell, 1976). Factors associated with taste cues like sensory cues andolfaction is responsible to influence the avoidance behaviour.

PERSISTENCE OF BAIT SHYNESS

Mostly all the rodent species exhibit bait shyness even after singles exposure to a sub lethal dose of zinc phosphide (Table 1). However, the period of persistence of this shyness remains for varying number of days in different species with a minimum of 10 to 15 days in *Gerbillus gleadowi* and a maximum of 170 days in the case of *Mus platythrix* (Table 1). The magnitude of bait shyness is directly related to the quantity of poison present in the food consumed by the rodents and longer the exposure to a poison bait more persistent is the bait shyness (Bhardwaj and Prakash, 1979a). Moron and Gallo (2007) claimed that food neophobia is an innate phenomenon and that it persists in genetically wild rats, even those reared in a laboratory (Barnett, 1958; Galef and Whiskin, 2003). However, some researchers have suggested that food neophobia may be primarily a response learned in the process of socialization (Barnett, 1956, 2005; Taylor and Thomas, 1989). The new container in which new food is served appears also to play an important role than food neophobia itself (Inglis et. al., 1996).

Table 1. Zinc phosphide induced bait-shyness persistence in Indian rodent species

S.No.	Rodent Species	Persistence of bait shyness (Days)	Source
1.	*Funambulus pennant*	30	Kumari and Prakash, 1981
2.	*Gerbillusgleadowi*	10-15	Rana et. al., 1975
3.	*Tatera indica*	115	Prakash and Jain, 1971
4.	*Meriones hurrianae*	35	Prakash and Jain, 1971
5.	*Rattuus rattus*	75	Prakash et. al., 1975
6.	*Rattus meltada*	135	Prakash et. al., 1975
7.	*Mus musculus*	20	Rao and Prakash,1980
8.	*Mus booduga*	95	Rao and Rajabai,1978
9.	*Mus platythrix*	75	Rao and Rajabai,1978
10.	*Mus platythrix*	170	Sridhara and Srihari, 1980a
11.	*Bandicota bengalensis*	30	Sridhara and Srihari, 1978
12.	*Rattus cutchicus*	75	Prakash et. al., 1975
13.	*B. indica*	105	Sridhara and Srihari, 1980b

SHYNESS BEHAVIOR TOWARDS ZINC PHOSPHIDE

Adding sub lethal dose of zinc phosphide in preferred food (millets) of *R. rattus* in choice test with plain sorghum, the reversal of food preference was observed as the intake of sorghum increased and the intake of millet declined significantly (Bhardwaj and Prakash, 1982). Even when the poison was removed from the food, the rodent showed a sharp aversion to plain millet flour also and continued to feed on sorghum flour on large quantities exhibiting bait shyness towards the preferred food which earlier carried poison. It persisted for 75 days (Prakash et. al., 1975). It is interesting that the hairy footed gerbil, *Gerbillus gleadowi* associated the sickness developed due to feeding upon a sub lethal dose of zinc phosphidemixed in the food with food itself (Rana et. al., 1975) but the rejection of candidate baitin the case of this species is much higher than that of the two gerbils viz. *Tatera indica* and *Meriones hurrianae* (Prakash and Jain, 1971) and three species of the rats, viz. *Rattus rattus rufescens*, *Rattus meltada* pallidior and *Rattus c. cutchicus* (Prakash et. al., 1975). The duration of exposure to zic phosphide also lasts for only 10-15 days in *Gerbillus gleadowi* against 35—135 days in others five rodentspecies (Rana et. al., 1975). The duration of poison shyness increases with the exposure period in *M. musculus* (Rao and Prakash, 1980). Bait shyness persisted in the house mouse for only 20 days after a single day exposure to poison bait, while it lasted for 30 after 4 days continues exposure. Cowan (1978) found that the development of bait shyness could not be retarded even when a poison was given once in week or in a mixture of highly preferred baits or changing the bait on subsequent days of poisoning and hence, confirmed the earlier recommendation of poison baiting for a single day only. Experiments with *R. norvegicus* (Hankin et al., 1973) and *R. rattus* (Barnett et.al., 1975) indicated that once the avoidance has developed, the discrimination does no longer depend on the olfactory sense but it is probably the taste organs which are responsible for it.

SHYNESS TOWARDS OTHER ACUTE POISONS

Unlike the zinc phosphide, rodents did not exhibit bait shyness when they were feeding on bait containing another acute rodenticide- RH-787 (Chopra, 1980; Rao and Prakash, 1980; Sridhara and Srihari, 1978, 1980a, 1980b; Sood and Gill, 1981). However, *R. rattus* (Bhardwaj and Prakash, 1979) and *M. platythrix* (Sridhara and Srihari,1980a) exhibited persistence of bait shyness due to exposure to a sublethal dose of RH- 787 for 4 days, as well as for a a single exposure respectively, for 42 and 120 days respectively. Likewise, red squill and barium carbonate (Rzoska, 1954) and the anticoagulant Dicoumarol (Armour and Barnett, 1950) also initiated aversive behavior. It is reported that in the deer mouse, *Peromyscus maniculatus* that the retention of Compound 1080 associated memory lasted upto 8 months (Howard et.al., 1977).

SHYNESS BEHAVIOR AND NEOPHOBIA

Rodents exhibited a typical new object aversion reaction (neophobia) when an unfamiliar object was placed in their familiar environment. This reaction persisted for 2 to 8 days in the desert gerbil, *M. hurrianae* (Advani and Prakash, 1979) and for 2 to 3 days *Rattus rattus* (Bhardwaj and Prakash, 1982). This neophobic behavior may be a component associated in the phenomenon of trap shyness (Ryley, 1913; Prakash, 1964). Another study indicated new place aversion reaction (Neophobia) by *Meriones hurrianae* (Mathur and Prakash, 1980) and in *R. rattus* (Bhardwaj and Prakash, 1982).

MITIGATION OF SHYNESS BEHAVIOR

Zinc phosphide is the chief acute rodenticide available in India which is used in large-scale control campaigns. Our studies clearly indicate that it should not be repeated in a single control operation. Since no other efficient toxic chemicals are available, attempts were made to migrate shyness behavior of rodents by altering the components of the baits or thebaits itself, by mixing the sebum exudation of the scent marking gland or conspecific urine, to the poison bait.

MITIGATION OF POISON AVERSION AND BAIT SHYNESS

Studies on the changing the bait vegetable oil, duration of poisoning and the poison itself to mitigate the bait shyness developed due to phosphide in rodents were conducted by Prakash and Ojha (1978) and by Bhardwaj and Prakash (1979a). However, the changing bait components did not reduce the persistence of the bait shyness. Bhardwaj and Prakash (1979b) observed that if two additives of a previously rejected baits e.g. sugar and groundnut oil, are mixed in a new food of which *R. rattus* had no experience, the shyness continued, the effects being more severe with latter component. Bait shyness among *R. rattus* could be reduced to some extent if whole grain of the bait were replaced by theirflour or cracked for in successive subsequent poison baiting trials (Bhardwaj and Khan 1978, 1979a, b).

It observed that when poison –shy desert gerbils were exposed to millet +zinc phosphide + sebum of the scent marking gland of male as well as female gerbils, in separate sets of experiments (Prakash, 1985), the intake of poison bait increased significantly ($P<0.05$) as compared to the intake of poison bait without sebum. The relative efficacy of urine in masking shyness behavior was also compared for that of sebum. *M. hurrianae* were exposed to sebum and urine mixed poison food in two arms of a plus maze in multiple choice experiments. It has been observed that the intake of urine mixed poison millet was significantly more than that of the poison food mixed with sebum ($P< 0.01$). Almost similar results were obtained when the experiment was repeated on *T. indica* (Kumari and Prakash, 1984).

CONCLUSION

These studies indicates that while a number of usually accepted food additives like sugar, salt and vegetable oils had little or no phago-stimulatory effect on rodents, addition of even small quantities of conspecific urine or minute amounts of mid ventral scent marking gland exudation (sebum) could mask the shyness behavior induced in the rodents after consuming sub lethal of acute poison , zinc phosphide baits. The studies carried out on this new aspect at Central Arid Zone Research Institute, Jodhpur, Rajasthan, India opens a new line of research, promises a major breakthrough in rodent pest management through effective manipulation of the faculty of olfaction.

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TRANSMISSION POTENTIAL OF PARASITIC DISEASES BY RODENTS TO ANIMALS AND HUMANS

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INTRODUCTION

Rodents belong to the order Rodentia, the largest group of small mammals. They are cosmopolitan in distribution. Rodents have been identified as the most important mammalian pests at the global level, constituting about 43% of the mammalian population. Further, they are highly successful animals due to their prolific breeding and high adaptability to a range of environments. In addition to their role as serious pests of crops (Singla and Babbar 2010, Singla and Parshad 2010) and stored food grains, different species of rodents have now become an increased source of pathogens affecting human health (Singla et al 2008a, b).

The frequency of disease transmission is facilitated by the close association and physiologic similarities that rodents have with man and other animals. Furthermore, their habits of utilizing kitchen wastes and sewage and their agility makes them a successful vector for various diseases. Rodent borne diseases like rat bite fever, murine typhus, leptospirosis, toxoplasmosis, trichinosis, salmonellosis and the plague have so far accounted for the death of more than 20 million people. Rodents are known to transfer more than 60 diseases to humans and the list is still growing as more and more research on zoonosis continues.

Many different species of rodents harbour a number of ecto and endoparasites of great zoonotic importance and thus have played havoc with human society by transmitting diseases. Infection in humans generally occurs directly through contact with rodent excrements, through ingesting food contaminated with their fur, feet, urine or fecal droppings, through rodent bites and indirectly through bites from ectoparasitic vectors such as fleas, lice, mites and ticks. In either case, the number of different diseases of varying degrees of severity is surprisingly large.

Though, rodents are involved in the transmission of a variety of parasitic diseases found around the world, yet the parasitic infections which rodents harbour and convey to human or animal populations have not been as thoroughly investigated, especially in India. Their association with man and domestic pests on one hand and exposure to blood sucking arthropods, beetles, cockroaches and other invertebrates on the other, enlarges the scope for parasitic transmission.

A. HELMINTH PARASITES

The helminth parasitic fauna harboured by rodents is dominated by the nematodes, followed by the cestodes, digenetic trematodes and acanthocephala. The mixed infection with different species of cestodes, nematodes, trematodes and acanthocephalan worms varied according to the rodent species and area of distribution. To determine the kind of helminthic species infesting three rodent species predominant in irrigated and dry land agriculture and commensal situations, respectively in Punjab namely, *Bandicota bengalensis, Tatera indica* and *Rattus rattus* were live trapped with multicatch rat traps. Individual rats were mostly found infected with more than one species of parasites. Different helminths recovered included *Cysticercus fasciolaris, Hymenolepis diminuta, H. nana, Railletiena* spp., *Moniliformis moniliformis*, *Trichuris* spp. and an unidentified Trichostrongylid nematode in cauda epididymal fluid (Singla et al. 2008a).

In another experiment, we screened 83 mature *Bandicota bengalensis*, live trapped from premises near railway station, fish market and agricultural fields in Ludhiana district of Punjab province, India to assess the natural occurrence of helminth parasites and their potential as reservoirs of zoonoses. On necropsy, intestine of rats was found infected with adult cestode parasites of *H. diminuta* and *H. nana*. Liver was found having concurrent infection of *C. fasciolaris* and *Capillaria hepatica* (Singla et al. 2013).

1.Nematodes (Round worms)

The most common groups of nematodes encountered in rodents belong to the orders Spirurida, Oxyurida and Strongylida. Among the nematodes of public health and veterinary importance are *Trichinella spiralis*, *Angiostrongylus* spp., *Capillaria hepatica*, *Baylisascaris procyonis* and *Toxocara canis* which are discussed in detail as under:

a) *Trichinella spiralis*

Trichinella spiralis is found in the muscles of domestic animals and causes the disease known as trichinellosis. In nature, rats are the common reservoir hosts of the parasite and become infected usually by eating other infected rats. In the city abattoir of Santiago, *T. spiralis* was found in 25% of *Rattus norvegicus* examined (Acha and Szyfres 1983). Pigs, dog, cats and other animals also acquire *T. spiralis* by eating infected rats or by eating food containing infected rat feces. Humans usually become infected by eating raw or improperly cooked pork. Transplacental trasnsmission of larvae occurs in mice and humans, but not in pigs.

b) ***Angiostrongylus* spp.**

The rat lungworms of the genus *Angiostrongylus* are of considerable public health importance in certain areas because they can be transmitted to humans and produce eosinophilic meningitis or cerebral angiostrongylosis. These lungworms utilize certain molluscs and prawns as intermediate and paratenic hosts, respectively where the parasite develops to the infective third stage larva. In the rodent host, the infective larvae invade and partially develop in the brain before travelling to the lungs producing extensive pathological lesions. Human infections occur when raw or undercooked molluscs or prawns containing infective larvae are ingested accidentally. Although the parasites do not develop to maturity in man, the third stage infective larvae migrate to the brain producing eosinophilic meningitis. The disease is confined to tropical and subtropical belts in areas conducive for the propagation of rodents and molluscan intermediate hosts.

Although there are several species belonging to the genus Angiostrongylus the main species involved is a bursate lungworm, *A. cantonensis*. Rodents which have shown pulmonary infection with adult *A. cantonensis* include species of the genera *Rattus*, *Melomys*, *Meriones* and others. The first record of its presence in India was made by Parmeter and Chowdhury (1966).

Another species of public health importance is *A. costaricensis* of rodents in South America which causes abdominal strongylosis. Human cases were reported from Costa Rica and Mexico to Brazil, in which the parasite was localized in the mesenteric arteries causing both inflammatory and circulatory problems.

c) ***Capillaria hepatica***

Capillaria hepatica is a natural parasite of a number of rodents all over the world and several human cases have also been reported. The adult worms deposit eggs which do not pass out in the faeces but accumulate in the liver and form large whitish spots under the surface. When infected livers are eaten through cannibalism by other rodents or through predation by cats or other animals, eggs escape and appear in the faeces of these animals, complete their development and become infective. Ingestion of embryonated eggs either through dirt or contamination of food appears to be the cause of human infection. Anantaraman (1966) reported infection of *Capillaria* in the bandicoot rat in Madras, sometimes in association with *C. fasciolaris*. We have also reported the natural occurrence and pathomorphological alterations of *C. hepatica* infection alone and in concurrence with *C. fasciolaris* infection in the liver of *Bandicota bengalensis* (Singla et al. 2016). Based on our study, we concluded that in view of the great potential of adult female, *C. hepatica* worms for production of large number of eggs and their zoonotic importance, it is necessary to prevent the incidence of this disease by taking proper sanitation and rodent control measures around animal and human dwellings.

Reports of 37 cases of hepatic capillariasis from throughout the world indicate its predominance in Japan, India, America, Canada, Brazil, Germany, Italy, Korea and Czechoslovakia. Most of the reports are in children from one to five years of age. The contamination of playgrounds by infective eggs can explain the higher susceptibility of children to capillariasis. Additionally, the infection is usually more severe in children than in adults.

Rodents act as primary hosts of *C. hepatica* and play basic role in the maintenance of infection in a population. The infective stage of *C. hepatica* inhabits the liver of different species of rats such as house rat (*Rattus rattus*), Malayan field rat (*R. tiomanicus*) and Norway rat (*Rattus norvegicus*). Rats and mice act as main reservoir and source of infection in different rural and urban areas of the world. A number of cases of capillariasis have been documented in humans all over the world. It may lead to death or is associated with chronic fever, hepatomegaly, hypereosinophilia, liver fibrosis and necrosis. Children of one to five years become most common victims of this disease by ingesting food contaminated by infected rodents. The adults of *C. hepatica,* ranging from four to 12 cm in length, lay eggs in liver parenchyma of host. The unembryonated eggs may either be released due to decomposition of the carcass or cannibalism of the vector into environment. Eggs become embryonated and infective during suitable temperature and humidity in their environment. Infection of healthy host occurs by ingesting first-stage larvae in embryonated eggs. These larvae reach the liver parenchyma via hepatic portal system, attain adulthood and die after depositing eggs.

d) *Baylisascaris procyonis*

Baylisascaris procyonis, a ubiquitous roundworm infection of raccoons and rodents is increasingly being recognized as a cause of severe human disease. Because the disease is transmitted by the fecal-oral route, human cases of B. procyonis infection typically occur in younger age groups, mainly infants, who often engage in oral exploration of their environment and are therefore likely to be exposed to B. procyonis eggs. The first human case of *B. procyonis* was reported in 1984 in a 10-month-old infant with fatal eosinophilic meningoencephalitis (Huff et al. 1984). At autopsy, numerous granulomas containing larvae of *B. procyonis* were observed in several organs and tissues. The brain was the most heavily affected. Although relatively few human cases of baylisascarosis have been reported, several factors suggest that the likelihood of exposure and infection may be greater than is currently recognized.

More than 90 species of wild and domesticated animals have been identified as infected with *B. procyonis* larvae (Kazacos and Boyce 1989). Another species *B. transfuga* reported from sloth bear has the potential to infect number of accidental hosts and has been proved to generate visceral, neural, or ocular larva migrans syndromes in different animals including rodents (Moudgil et al. 2014).

e) *Toxocara canis*

The infective eggs of *T. canis* are ingested by non-canine hosts such as rodents or humans accidentally. The larvae after hatching travel to the tissues where they remain unless the tissues of these hosts are eaten by a canine host, in which case they are reactivated. In children, disease is most often recognized when a larva migrates to an eye and causes local injury.

2. Cestodes

Cestodes constitute the second largest group of the helminth parasites of rodents. The cestode fauna of rodents is dominated by hymenolepids and anoplocephalids. Species of the genera Hymenolepis synonym Rodentolepis or Vampirolepis are the main hymenolepids encountered. Rodents act in a dual capacity as hosts for cestodes. Not only are they final hosts for adult cestodes belonging to several genera but they are also intermediate hosts in which larval cestodes, particularly those of the family Taeniidae, such as hydatid cysts, cysticerci and strobilocerci are found. Among the cestodes of public health and veterinary importance are *H. nana*, *H. diminuta*, *Raillietina* spp., *Echinococcus multilocularis*, *E. oligarthrus* and *C. fasciolaris*. All of these parasites have been reported to be pathogenic to humans but hymenolepiasis in children is the most frequently reported problem. In most cases the infection is subclinical but when they occur the signs in humans are due to the damage caused to villi of the small intestine. Infection is transmitted to humans through ingestion of eggs on faecally contaminated fingers, or from contaminated water or food.

a) Hymenolepis nana

The dwarf tapeworm, *H. nana* (also known as *Rodentolepis nana, Vampirolepis nana, Hymenolepis fraterna*, and *Taenia nana*) has a cosmopolitan distribution in man and rodents. Rodents are the reservoir hosts. Infection is by the oro-fecal route and, hence, cross infection and auto infection by eggs in feces is normal. The worm develops from ingested eggs into an adult in the small intestine and resides there for several weeks. Light infections produce vague abdominal disturbances but heavier infections may cause enteritis. Rats are important epidemiological factors as the disseminators of *H. nana* to humans. Because of the unusual life cycle of this species, where no intermediate host is essential, man is probably the main source of human infection. Young children can be infected with *H. nana* eggs from rodent sources.

The length and width of *H. nana* varies from 25 to 40 mm and less than 1 mm, respectively. Four unarmed suckers are present on its scolex whereas a single ring of 20- 27 small hooklets are present on rostellum. This parasite inhabits the small intestines of rats and mice that may transmit it to humans.

b) Hymenolepis diminuta

Another small tapeworm capable of infecting people is *H. diminuta*. This is the tapeworm, which occurs more frequently in rats. This common parasite of rats was first reported from man by Weinland in 1858. Marangi et al. (2003) reported *H. diminuta* infection in a two-year-old child living in the urban area of Rome, Italy. Rats act as natural reservoir of the infection in man. Various insects, including fleas are obligatory intermediate hosts of this cestode. The final hosts, including man, acquire infection by ingesting insect intermediate hosts harbouring the cysticercoid larval stages. Grain beetles that infest cereal, flour, or dried fruit are the most likely source of infection. It has recently been reported that beetle-to-beetle transmission of *H. diminuta* occurs in natural environments and that eggs can be dispersed in the environment via beetle feces thereby representing a source of additional infections and a mechanism of egg dispersal.

H. diminuta has a worldwide distribution whose definitive hosts are rodents. Infection of humans is rare and occurs by accidental ingestion of infected arthropods. Although *H. diminuta* infection is often asymptomatic yet abdominal pain, irritability, pruritis and eosinophilia have been associated with this condition.

***c) Raillietina* spp.**

Several species of the davainid cestode of genus Raillietina are normal parasites of' rodents, but some of species such as R. madagascariensis, *R. celebensis* and *R. garrisoni* have also been recorded occasionally from man particularly children. Insects serve as intermediate hosts of Raillietina spp.

d) Echinococcus multilocularis

Rodents play a major part in the transmission of the cestode, *E. multilocularis*. The adults of this species are generally found in the red fox, arctic fox, dog, cat and other carnivores. Wild rodents particularly of the genera Microtus, Peromyscus and Clethrinomys are intermediate hosts. Many human cases have been reported, particularly in fur trappers who ingest eggs while skinning wild animals. A domestic cycle is also established with dogs and cats as final hosts and house mice as intermediate hosts. In man, the alveolar or multilocular hydatid cysts form pseudomalignant growths with a spongy mass of proliferating vesicles embedded almost always in the liver causing necrosis of the surrounding liver tissues have been found.

e) Echinococcus oligarthrus

E. oligarthrus occurs naturally in wild feline. Infection of man with this species is rare. Wild rodents serve as intermediate hosts. This is a tapeworm, similar to *E. granulosus*, that causes hydatid disease in herbivores. Humans infected with this worm also develop hydatid cysts which produce symptoms similar to those caused by *E. granulosus*. However, the cysts are multilocular (consisting of many chambers).

f) Cysticercus fasciolaris

C. fasciolaris is the larva of *Taenia taeniaeformes* tapeworm of cats. The adult form of *T. taeniaeformis* is found in both domesticated and wild cats, whereas its immature form (metacestode stage) is prevalent in the rodents that serve as its intermediate hosts. The infection rate of *C. fasciolaris* was found to be 25.7% in *B. bengalensis* in Punjab (Singla et al. 2003a). Cats in the area from which rats were found positive for *C. fasciolaris* were found passing *T. taeniaeformes* eggs.

Rodents ingest eggs that develop into larvae inside them. These larvae migrate in their intestinal wall and strobilocercus develops in the liver. This strobilocercus measures 60 to 100 mm in length and becomes infective for its final host i.e. cats in approximately two months.

3. Trematodes

The digenean trematode parasites encountered in rodents are few in comparison to the nematodes or the cestodes. The digenea of rodents are rich in representatives of the family Echinostomatidae where species representing several genera are found. Species belonging to the families Notocotylidae, Brachylaimidae, Heterophyidae, Microphalidae, Paragonimidae, Schistosomatidae and others are also reported. Yamaguti (1958) and Niphadkar and Rao (1966) reported two species namely *Schistosoma spindale* and *Artyfechinostomum sufratyfex* from rats in India. Among the major digenetic trematodes infecting humans and other animals are *Schistosoma mansoni, S. japonicum, Paragonimus* spp. and *Echinostoma ilocanum.*

***a) Schistosoma* spp.**

Human schistosomiasis is caused primarily by the 3 species of blood flukes namely *Schistosoma mansoni*, *S. haematobium*, and *S. japonicum*. For two species, *S. haematobium* and *S. mansoni*, the principle host mostly is man, while *S. japonicum* also infects domestic animals such as water buffaloes, dogs, cats, pigs and rodents. The important role of reservoir hosts in transmitting the disease to humans is revealed by finding several species of animals naturally infected and passing viable eggs in their faeces. The most striking observations were made in South America where very high natural infection rates with *S. monsoni* in many species of rodents of the genera *Rattus, Cryzomys, Nectomys, Cavia* and *Holochilus* were demonstrated (Barbosa 1972).

In infections caused by *S. haematobium*, man is the main definitive host and rodents do not play any significant part in its transmission in nature. Man may be the source of infection of *S. japonicum* in the Far East for many species of animal hosts and vice-versa where man can become infected from animal sources. Rats and mice play a major part in the epidemiology of this parasite. In some parts of the Philippines, 23% of rats were found naturally infected with this parasite (Muller 1975). *S. rodhaini* and *S. matthei* infect a number of species of animals including rodents, but man is sometimes accidentally infected with these species.

b) Paragonimus spp.

A large number of mammal species have been found to be naturally infected with various species of Paragonimus. *P. kellicotti* is a parasite of rodents particularly the muskrat of the genus Ondatra in America but only sporadic cases of human infection have been reported. *P. heterostomum* has been reported from rats in China but reports of human infection with this species have been made in Thailand and Laos (Miyazaki 1982).

c) Echinostoma ilocanum

Species of various genera of the family Echinostomatidae are parasites of mammals and various other hosts, but man occasionally becomes infected. *E. ilocanum* infects various rodents and other mammals in addition to man in the fareast.

4. Acanthocephalans

M. moniliformis, a cosmopolitan parasite of rats has been recorded in India. Sita (1949) had traced its development through the cockroach in Madras, and found the heaviest infection rate in the insect to be 911 cystacanths. Single human infections are reported from Italy, the Sudan and British Honduras, and two suspected cases in Florida and East Pakistan. Rodents infesting sewers, granaries and store-houses are more susceptible to the infection than field rodents, as darkness and moisture would favor cockroach populations. Crushed insects in grocery shops have been seen to scatter infective larvae around, and contamination of grains and cereals with them could result in human infection.

B. PROTOZOAN PARASITES

Protozoa recorded from rodents include *Plasmodium ratufae*, *Hepatozoon* spp., *Wenyonella hoarei, Grahamella muris, Trypanosoma lewisi, T. cruzi, T. bandicoti, T. indicum, Leishmania tropica, L. donovani, L. brasiliensis, Toxoplasma, gondii, Giardia lamblia, Cryptosporidium muris* and *Babesia microti*. *T. lewisi*, a non-pathogenic form transmitted by fleas, is common in *R. rattus* and *R. norvegicus*. *Trypanosoma evansi* could be experimentally established with ease in laboratory rodents but no natural infection in field rodents is on record (Singla et al. 2003b). Rodents are naturally exposed to the cysts of *Entomoeba histolytica* or *Balantidium coli* in drains and slum areas, but their ability to disseminate the infection is little understood. Major protozoans of veterinary and public health importance are discussed as under:

a) Leishmania spp.

Rodents have an important role in the epidemiology of leishmaniasis. The major *Leishmania* species infecting humans are the *L. donovani* causing visceral leishmaniasis (kala azar) and *L. tropica* and *L. brasiliensis* causing cutaneous leishmaniasis. Visceral leishmaniasis is distributed all over the world, but predominantly is encountered in India, South America, Central Asia, Middle East, and Africa. Cutaneous leishmaniasis caused by *L. tropica* is seen mainly along the shores of the Mediterranean, through the Middle East, central Africa and parts of India. Cutaneous leishmaniasis caused by *L. brasiliensis* is confined mainly to Central America and South America. Studies on the animal reservoirs demonstrated the presence of Leishmania parasite in the blood of rats.

Although cutaneous leishmaniasis exists in many countries where *L. donovani* is prevalent, the two parasites are not present in the same region. In India, visceral leishmaniasis is confined to the eastern parts, while cutaneous leishmaniasis is limited to the dry western parts. Leishmaniasis is spread by the bite of some types of phlebotomine sand flies which become infected by biting an infected animal (for example, a rodent or dog), or a person. The risk for leishmaniasis is highest from dusk to dawn because this is the time when sand flies are the most active. The reservoir of infection in Indian kala azar is humans, whereas it is rodents in African kala azar, foxes in Brazil and Central Asia, and canines in the Mediterranean and Chinese kala azar.

Leishmaniasis is essentially a disease of rodents caused by *Leishmania* major transmitted to humans by sand flies. Gradoni et al. (1983) suggested that the black rat acts as *L. infantum* reservoir when rats were experimentally exposed to *L. infantum* and found them resistant to the parasite. The sand flies (*Phlebotomus perniciosus* and *P. perfiliewi*) feed on rats and cause infection and sub patent immunodepression in rats which is cause of infection in rats.

b) Toxoplasma gondii

Toxoplasma gondii is a ubiquitous, obligate, intracellular apicomplexan coccidian zoonotic protozoan parasite transmitted within and between different host species by many portals. It is capable of infecting a variety of animals including humans and warm-blooded domestic and wild animals such as birds and rodents. Warm-blooded animals, including humans and rodents act as intermediate hosts that harbor tissue cysts in their bodies. The definitive host for *T. gondii* is the cat. The cat is the only animal that passes oocysts in their feces. The oocysts are not infective until they sporulate. This takes 1-5 days after they are excreted in the feces. Its severity in man can range from inapparent infection to a severe systemic disease which may lead to death. Intermediate hosts are swine, cattle, sheep, goats, chickens and many species of rodents. Cats become infected by eating mice, rats, birds or meat contaminated by *T. gondii* cysts. The disease may pass to man either through consumption of poorly cooked meat with Toxoplasma cysts, or by consuming food or water contaminated by oocysts from cat faeces.

Rats are considered as the main reservoirs for this protozoan parasite since they can live in proximity to humans. The relatively high incidence of *T. gondii* infections in rodents underlines the risk for cats to become infective by predation on infected rodents. Rodents might be an important linkage for disease transmission via the food chain. They are the main source of T. gondii infection in humans in Kuwait either through consumption of infected rodent species and to a lesser extent through contamination from cats which have consumed infected rodents. In studies on toxoplasma infection in Egypt, *R. norvegicus* was found as reservoir for this parasite. Cockroaches may also serve as mechanical vectors of *T. gondii*, through ingestion of oocyst containing cat feces. Rodents also become infected when they consume contaminated cockroaches.

Common species of commensal rats have been reported as potential chronic vectors of *T. gondii* infection to cats and other livestock animals and humans. Effects of *T. gondii* on rodents are unique; most flee cat odour, but infected ones are mildly attracted to it. This is because *T. gondii* have the ability to permanently alter a specific brain function in mice, and is known to remove rodents' innate fear of cats (Ingram et al. 2013). Even months after infection, when parasites are no longer detectable, the effect remains. This raises the possibility that the microbe causes a permanent structural change in the brain. This is thought to be an evolutionary adaptation to help the parasite complete its life cycle as Toxoplasma can sexually reproduce only in the cat gut and for it to get there, the pathogen's rodent host must be eaten.

c) Trypanosoma species

Trypanosoma cruzi causes American trypanosomiasis or Chagas disease in man. The parasite is found throughout much of central and northern South America, Central America and Mexico. *T. cruzi* is found in a number of animals besides humans, including dogs, cats and rodents, however, it remains unclear whether the *T. cruzi* found in these reservoir hosts can actually be transmitted to humans. The vector for Chagas disease is a true bug of order Hemiptera and genera *Triatoma, Rhodnius* or *Panstrongylus* which ingests amastigotes or trypomastigotes when it feeds. In the vector, the parasite reproduces asexually and metacyclic trypomastigotes are found in the vector's hindgut. The vector defecates on the host's skin at the same time that it feeds, and the metacyclic trypomastigotes enter the host's body, most often by being rubbed into the vector's bite or the mucous membranes of the eye, nose, or mouth. In the human host, Chagas disease affects primarily the nervous system and heart.

T. lewisi is non-pathogenic flea borne parasite of rodents whereas, *T. evansi* is a widely prevalent species infecting broad, vertebrate host range of animals with tabanid flies as invertebrate vectors. Three cases of human *T. evansi* have been reported from the Indian subcontinent (one from Sri Lanka and two from India) during the last decade. Apart from these three cases, at least six more atypical human cases of trypanosomosis caused by rat trypanosome, *T. lewisi* have been reported. Two casualties due to non-tsetse transmitted trypanosomosis were also reported from India. High prevalence of these two animal trypanosomes in India is now a matter of concern for public health specialists (Parashar et al. 2016).

A rodent reservoir and flea vector appeared to be the most likely source of *T. lewisi* like infection. *T. lewisi* infects two species of rats, *R. rattus* and *R. norvegicus*. It cannot grow in mouse. It is transmitted by ingestion of rat fleas or contamination of wound by rat flea faeces having trypanomastigotes.

d) Cryptosporidium spp.

Cryptosporidium, an important enteric protozoan, is hosted by a number of animal groups including mammals, birds, reptiles and fish. In humans, cryptosporidiosis is caused predominantly by *C. parvum* and major outbreaks of the disease have been clearly associated with contaminated drinking water. Rodents such as house mouse (*Mus domesticus*), wood mouse (*Apodemus sylvaticus*) and Norway rat (*R. norvegicus*) are infected with different genotypes of *C. parvum* which may transmit infection to humans.

Another species *C. muris*, has been suggested to be of concern to human health. *C. muris*, a parasite first identified in the gastric glands of mice (Tyzzer 1910) and *C. parvum*, identified from the intestine of the same species of mice are the two rodent transmitted species. Nearly 40 rodent species belonging to 11 families have been reported to act as hosts of *Cryptosporidium* spp. with prevalence rates of 5 to 39.2%. Asymptomatic natural infections have been reported in rodents and hence are considered to be the reservoirs of cryptosporidiosis.

Experimental transmission studies have shown that the parasite readily infects multiple non-rodent hosts including dogs, rabbits, lambs and cats. In the past two years, five cases of infections with *C. muris* have been reported from HIV-positive and healthy persons in Kenya, France, Thailand and Indonesia. Palmer et al. (2003) reported the first documented case of C. muris in a man in the Western Hemisphere.

e) Giardia lamblia

Giardia is a flagellate protozoan with *G. lamblia* being the most significant with respect to human infection. Giardiasis is one of the most common causes of diarrhea in people living with AIDS. Transmission of the organism most commonly occurs through the fecal-oral route by the ingestion of cysts. Cats, dogs and small rodents such as hamsters and gerbils may carry the disease.

f) Babesia microti

Babesiosis is an emerging, tick-transmitted, zoonotic disease caused by hematotropic parasites of the genus *Babesia*. Babesial parasites are some of the most ubiquitous and widespread blood parasites in the world, second only to the trypanosomes, and consequently have considerable worldwide economic, medical, and veterinary impact. The parasites are intraerythrocytic and are commonly called piroplasms due to the pear-shaped forms found within infected red blood cells. The piroplasms are transmitted by ixodid ticks and are capable of infecting a wide variety of vertebrate hosts which are competent in maintaining the transmission cycle. To date, there are several species of Babesia identified that can infect humans, *B. microti* being the most prevalent for which rodents are the reservoirs.

CONCLUSION

From the above discussion, it can be seen that the rodents have the great veterinary and public health importance and indeed far greater than is generally realized. It must also be emphasized that the above listing is only a partial one and rodents are either the reservoirs, vectors or otherwise involved in the transmission of a number of other diseases which have not been mentioned. Nevertheless, the information presented will provide an idea of the order of magnitude of the parasitic diseases in which rodents play some part in their transmission and should provide an added stimulus and added argument for the necessity of establishing effective rodent control programmes.

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RODENT MANAGEMENT IN POULTRY FARMS

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It has now been recognized on a global scale that rodents cause problems in poultry farms. The Poultry industry is one of the major sources of man's food requirements throughout the world. Poultry farms provide the most favourable and stable habitat to host large populations of rodents, which inflict significant economic losses to poultry owners. This is because of the availability of abundant food from the feed and poultry products, constant temperature-controlled environment, freedom from predators and availability of large space for nocturnal activities of rodents throughout the year. Poultry farms provide a perfect environment to sustain dense breeding population of rats throughout the year.

Most of poultry farms in India are located in rural and semi-urban environments. Often these are poorly built and managed and are without proper rodent proof structures for storage of feed and eggs. The rodents frequently invade such premises from adjoining buildings and sometimes from agricultural fields and cause damage to poultry birds and their products. Rodents cause direct damage to poultry production by feeding on poultry feed, killing chicks, damaging eggs etc. and indirect damage by acting as vectors and spreading several diseases to poultry birds and workers through contamination of feed with their excrements. Rodents possess one pair of sharp chisel shaped incisors in each jaw and use them for gnawing. These teeth grow on average about 0.31-0.4 mm per day, and rodents have to curve these teeth regularly through gnawing; otherwise they will grow back into the cheek disabling proper feeding. Damaging to poultry house structures, egg trays, feed containers etc. is caused due to this gnawing behaviour of rodents.

Rodents are often difficult to control because of their complex behavior and adaptations and poor quality of poultry house premises which are frequently invaded by rodents. Also, after a successful rodent control, rodent rebuild up their population in a very short time by increasing their rate of reproduction. Post-control reinfestation rate is generally high which has been reported to be 41.8 rodents/100m2/month in poultry farm in Punjab. After 3 months of control, the population density of rodents reached to 58% of the original level. This is also because of large immigration of rodents due the abundant food supply and shelter in the poultry houses.

Despite of considerable advances in poultry production and management technology, the rodent problem continues to persist unabated in poultry farms throughout the country. Little attention is being paid to this problem by the poultry scientists and farmers. This problem was recognized by the All India Coordinated Research project. Rodent Control and the work on the biology and management of rodents in poultry farms was carried out at different centres of this Project located in different geographical regions of the country. Based on this work, a complete package on management of rodents in poultry houses was developed.

RODENT SPECIES IN POULTRY FARMS

Poultry farms in India are mainly found infested with the house rat, *Rattus rattus* (Fig. 1) and the house mouse, *Mus musculus* (Fig. 2). Of these, the house rat is most predominant in poultry farms located in both rural and urban conditions throughout the country. It is characterized by its slender body weighing 150-250 g, sharply pointed snout, grey or brownish grey belly, tail longer than the head and body length, large hairless ears, 5 pairs (2 pectoral and 3 inguinal) of mammary glands and banana-shaped faecal pellets. Breeding occurs throughout the year producing 5 to 7 litters a year. Gestation period is 20-22 days, show on an average 40% pregnancy rate, litter size ranges from 6-14 young and average annual productivity is about 69.9 young per female per year. It is a very good climber and jumper, frequently found on the overhead structures in the poultry farms. It can be seen in spaces left between girders and beams in the roof and insulation layers.

The house mouse is smaller in size usually weighing about 15-30 g with slender body and pointed snout, brownish grey fur, large hairless ears, 5 pairs (3 pectoral and 2 inguinal) of mammary glands and rod or spindle shaped faecal pellets like grains of rice. Mice can live from 5 to 12 months and can start breeding at around 50 days of age. They have a gestation period of 18-22 days and can begin breeding 14-24 hours after giving birth. This ability to breed at a young age, coupled with a short gestation period can result in mice having from 5 to 10 litters in a year with litter size ranging from 1-13. Average annual productivity is 21 young ones per female.

Breeding population of rats and mice occur throughout the year with frequent peaks in poultry farms. Continuous availability of good quality of food and harbourage favour their reproduction and survival. Occasionally, other rodent species such as the lesser bandicoot, *Bandicota bengalensis*, Indian gerbil, *Tatera indica*, field mouse, *Mus booduga* and the soft furred field rat, *Millardia meltada* are also found visiting poultry farms located near crop fields. The occurrence of these wild species especially *T. indica* in poultry farms may be drastic from the disease point of view. This species is resistant to plague bacillus and acts as its reservoir host.

 

Fig. 1. House rat, *Rattus rattus* Fig. 2. House mouse, *Mus musculus*

ECONOMIC DAMAGES

Rodents by their gnawing, burrowing, defecation and extensive nocturnal movements deteriorate the poultry farm's environment and cause extensive damage to poultry production and health. Because of the multivariate nature of their damage, exact losses are difficult to determine. As per some estimates, loss of Rs. 94/1000 birds and Rs. 15,000 while raising 20,000 broiler chicks has been reported in Punjab, Rs. 8744 in a medium sized poultry farm in Madhaya Pradesh and Rs. 0.63/100 eggs/day in Rajasthan. Rodents have been reported to cause 0.4% damage to eggs (Fig. 3) and 0.5% damage to chicks. An adult rat can consume 50g poultry feed/day. Samples of the floor scratch showed 2·7% contamination with rat hairs and 4·6% with pellets. Similarly, 3·3% of samples of poultry feed from godowns and 0·4% from feeders had signs of rodent contamination. These reports and the nature and extent of damage caused indicate that the total loss by rodents to the poultry industry in India would be in crores of rupees.

Fig. 3. Rodent damage to poultry eggs

STRUCTURAL DAMAGES

Rodents cause severe economic loss by causing damage to different structures and equipments in the poultry farms. They damage wooden doors, windows and electric cables by gnawing and floor and foundation by burrowing. Small farmers generally use thatched grass for making the roof which is severely damaged by the house rats. Damage caused to electric wiring may cause hazard or failure of lighting, heating or ventilation. Wire mesh of the rearing cages and houses is often damaged by rats. The feed stores are heavily infested with rats which establish their burrows in feed supplies and ruin bags used for storage and transport. Thus, it can be said that rats enhance maintenance cost of the building.

RODENTS AS SOURCE OF DISEASES

Rodents accelerate the spread of established diseases from one area to other through their urine, faeces, fur, saliva or blood. Infections of Salmonella bacteria are transmitted to poultry birds through contaminated feed and water and to man through infected eggs and meat of poultry birds. Several farm workers die due to Weil's disease. Almost every year large stock of birds dies with Newcastle (Ranikhet) disease. The exact role of rodents in spreading poultry diseases is not known but loss of crores of rupees occurs annually due to various diseases and expensive vaccination of flocks. An effective disease barrier may not be possible as long as rodents infest poultry farms. Plague bacillus is transmitted from the wild rodents to house rats, mice and humans by the bite of ecto-parasites, generally the rat fleas. Leptospira bacteria can be transmitted through feed and water contaminated with rat urine.

RODENT ACTIVITIES IN POULTRY FARMS

Though rats and mice occur in the entire premises of poultry house but they show maximum activity in the poultry feed godowns and egg stores which provide abundant hiding space and food to them. The occurrence of birds does not deter rats in sheds where they are often seen disturbing the birds and invading feeders and water hoppers for getting food and water. The house mice are frequently found on the ground around feed bags, storage bins etc.

The wild rodents, which generally dig burrows in the peripheral crop fields and vacant land around the poultry houses, are frequently attracted within the premises. They dig burrows in the foundation and floor and some of the burrows may have openings on both inside and outside the poultry house. Accumulations of garbage, waste material, weeds and bushes around the premises provide good nesting and feeding grounds to rodents. Rats and mice readily move from one location to other to seek alternative sites when disturbed, when the source of food is removed and when sheds are cleaned.

RODENT TRACES AND SIGNS IN POULTRY FARMS

Rodent populations mostly remain under-estimated based on rodent sightings alone. Therefore, other information is essential to confirm the rodent species involved and the level and distribution of infestation. Both rats and mice leave characteristic evidence of their presence which is useful for estimating the size and distribution of infestations. A combination of these signs has to be employed in the initial assessment of infestation and when evaluating the results of control action.

a) Droppings: Rats usually deposit faeces at specific locations throughout their territories. These are often found in areas where rats are regularly moving. Areas where there are greater accumulations of droppings are normally those where rats and mice are spending most of the time or passing through more frequently.

b) Damage: Identifying gnawing of building structures can be useful in locating and quantifying rodent activity. The discovery of chewed materials can also provide important information on the activities and distribution of rodents.

c) Run ways and burrows: Some rats burrow to build their nests while others prefer suitable nesting places above the ground. When checking for their presence look for holes into the floor as well as in suitable locations in bagged food, piles of empty bags and other equipment or material above ground.

d) Footprints: Footprints or tracks may be found in mud or dust at ground level. Such signs can provide useful information about the general location and movement of rodents.

e) Smear marks: The natural grease on the bodies of rodents attracts dirt that will be deposited at various locations that are used regularly by rats and mice. These appear as dark marks that are commonly found in association with holes in structures etc. Rats urinate at specific locations and the combination of concentrated protein in the urine and dust which settles leads to the formation of small conical marks that indicate rodent infestation.

f) Nest sites: Rodents will make nests from any available materials. Particular attention should be paid to areas where droppings accumulate. These can often reveal the presence of nests, particularly where mouse infestations are heavy.

g) Other signs: Reports of rodent sightings or pungent, unique smell that is present with heavy rodent infestations are other signs of activity.

RODENT MANAGEMENT

Management of rodents in poultry farms with birds around is complicated, time consuming and difficult. No single method is 100% effective and the effect are short-lived owing to the various behavioral and ecological adaptations of rodents. The severity of rodent damage can be tackled by adopting the various techniques in an integrated manner.

1. Method of poultry housing

There is direct relationship between the method of poultry housing and rodent infestation. California cage system of poultry housing, in which direct attack of rats on birds and eggs is prevented, had about 1/3 population of rodents and less damages than in the deep litter system of poultry housing.

2. Proper management

An ill managed poultry farm suffers severe damage by rodents. Timely turn-over and marketing of flocks to keep the sheds vacant for some time for cleaning and repairs and optimum storage of feed and eggs reduce severity of rodent attack. More damage occurs when the eggs and feed are stored at the same location for longer duration. Proper storage of feed, prevention of its spillage and timely removal of garbage and sewage, unserviceable equipments and weeds outside the farm reduce the hiding and nesting sites for rodents. Rats are attracted to garbage heaps and heaps of litter on the farms and periodic clean up operations reduce invasion by rats.

3. Inspections and surveys

Before control action is taken, a full survey of the site should be undertaken to identify potential rodent-infested areas. This needs to be carried out by expert personnel and repeated periodically in order to monitor the situation. It includes asking farm staff about their sightings of rodents and signs of rodent activities and performing a very detailed visual inspection of the premises. Inspection must include all buildings and structures within the unit and looking for possible entry points and signs of activity, store-rooms, stacked materials etc. The objectives of such an inspection are to:

- Identify the species of rodents involved
- Assess the distribution and level of infestation
- Identify where rats and mice are living, travelling and feeding
- Identify any factors which might have an influence on control action such as specific risks to non-target animals including stock and workers
- Identify deficiencies in proofing and tidiness or hygiene measures

4. Rodent proofing

Preventing rodent entry into the poultry houses by physical barriers at their entry points is the best approach. The proofing measures should be adopted while constructing the poultry houses and the existing premises can be made rodent-proof with some additional measures. The basic principle is to find out the entry points of rodents into the premises and sealing or blocking with proper material (Table 1). The design and the material used for construction of the building also affect the rodent infestation. Often the poultry houses with low plinth, open and damaged doors, windows and ventilators, roof with girders (Fig. 4) and thatched grass harbour more rodents than well designed houses with rodent proofing.

Fig. 4. Rodent found in between the girders on the roof

Table 1: Rodent-proofing techniques

Route of entry	**Rodent-proofing technique**
Rodents may enter poultry premises through uncovered drain holes, sewers and gutters	Fixing tightly fitted perforated metal sheet covers on drain holes and by keeping sewer and gutters properly covered
Rats climb along water and sewage drainage pipes and walls and also move along cables, ropes etc.	Installing aluminium guards on outside pipes (Fig. 5), by sealing space around holes used for cables, and by using guards (Fig. 6) around cables, ropes etc.
Rodents easily manage into the godowns, stores and poultry buildings having low plinth	Making plinth above the ground level using pillers and fixing an aluminium cone (Fig. 7) of about 1.5 feet diameter around the pillar or a platform around the plinth in the form of collar guard of 1-2 feet (Fig. 8) to prevent entry of rodents
Open and damaged windows and ventilators allow entry of rodents. Roof rats climb poles, pillars or other structures, and can enter inside	Fixing permanent screen of wire mesh with holes less than 1cm size. Structures near to windows and ventilators on which the rats may climb need to be removed
Rodents enter through holes in doors made by gnawing and open doors, and through under door space	Proper fitting of doors, fixing of galvanized iron sheet on lower border (Fig. 9), door sweeps and door closers to be used
Wild rodents dig burrows in foundation and floor through which they keep moving to and from the	Use concrete and mortar in foundation, floor and perimeter strip around the premises

premises and wild habitat	
The commensal rodents use cracks and joints for nesting and hiding	Sealing the cracks with concrete and fixing metal sheet on joints reduce their activities
Roof made by using girders, roof supports, thatched grass etc. provide sites for movements by roof rat around the premises	Roofs made of concrete slab provide no free surface for rats to move or climb (Fig. 10)

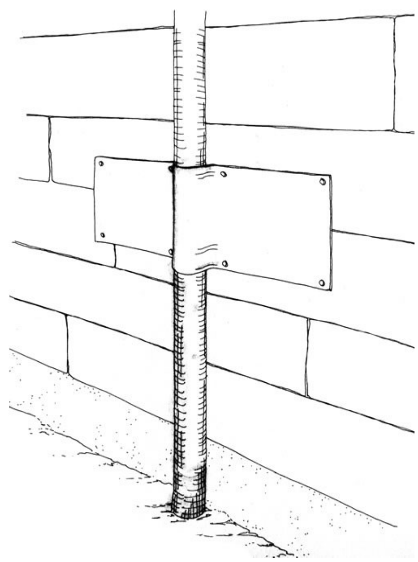

Fig. 5. Aluminium guard around outside pipes

Fig. 6. Guard around cables and ropes

Fig. 7. Aluminium cones on pillars

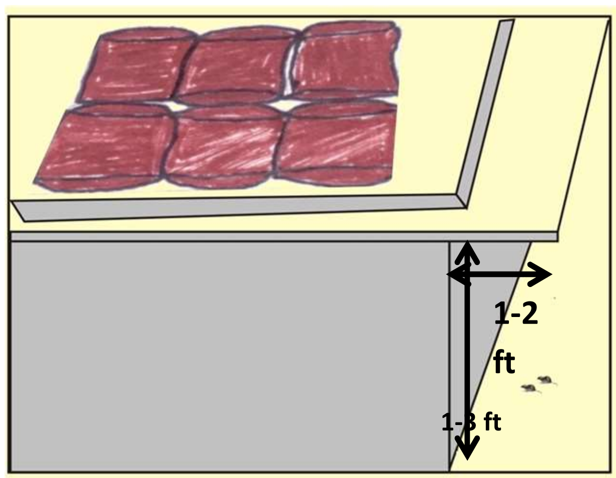

Fig. 8. Collor guard on the plinth

Fig. 9. Galvanized iron sheet on lower border of the door

Fig. 10. Roofs made of concrete slab

5. Use of rodent traps

Trapping is a safe, convenient and effective approach. Traps may be used to assess changes in rodent population if they are deployed in an effective and systematic way. Different types of traps can be used in poultry farms.

a) Multi-catch traps: Multi-catch traps are useful for trapping rodents in feed and egg stores as well as in rearing and layer houses because with these traps there is no danger of injuring the birds as with snap or glue traps. Moreover, the house rats and mice which live in social groups get easily trapped in groups as trapping of one of them facilitates that of others. Pre-baiting of traps reduces new object reaction and fixing a piece of paper on the entry of the cage reduces the thermal response. Success of trapping depends upon number of traps per unit area, location of traps density of rodents, their early experience towards traps, presence or absence of trap shy population and availability of the alternative food material. At least 4 traps/100 m2 area should be set. Catching rats with more traps for few days than using few traps for more days is effective in reducing rodents in poultry farms. Traps should be placed along the walls of vertical surfaces and location should be changed frequently. It is often difficult to trap few scattered individuals for which some other techniques should be adopted.

b) Single catch traps: These are single rat catch traps and are effective for trapping the house rats and mice in poultry houses. Their use does not involve much risk for injury to birds.

c) Glue traps or boards: The glue trap is a disposable type of trap that utilizes highly viscous and sticky substances based on polybutanes, an important by product of petroleum industry. The glue is spread on card board surface. These boards are placed in the rodent habitats along the walls or vertical surfaces and the moving rodents get stuck on the glue and cannot escape. These are highly effective in trapping rats and mice and even the trap or bait shy individuals (Fig. 11), but because of risk of getting the birds stuck to the glue these cannot be placed in rearing and layer houses. Moreover, their use is unhygienic as the individual that gets entangled in the glue try to escape, and death may be painful.

Fig. 11. Glue trap with rat stuck over it

6. Use of rodenticides

Control of rodents with chemical rodenticides is the common approach but in poultry farms, it involves potential risk of primary and secondary hazards of poisoning the birds. Fumigants like aluminium phosphide should not be used in poultry farms. Poison baits of acute (e.g. zinc phosphide) and chronic rodenticides (e.g. bromadiolone) are commonly found in India and have been found effective in laboratory and field studies against rodents in poultry farms. Their method of bait preparation and application in poultry farms is given below.

a) Bait formulation: Sometimes the rodents while carrying food material from one place to the other for hoarding and eating in their hiding places, spill the food material if it is grain or piece of bread or chapatti or wax block. Such materials should not be used in poultry houses as it may be risky for poultry feed and production. Therefore, powdered or fine bait should be used which rodents cannot carry with them.

i) Preparation of 2% zinc phosphide bait: Zinc phosphide is highly toxic causes rapid death and rats which ingest lethal dose die within 12 hours. Therefore, it is possible to collect dead rats in the next morning. Poison baiting with this rodenticide should be carried out for 1-3 days so that most of the rats get opportunity of coming in contact with the bait. There is no antidote for this rodenticide, in case of accidental poisoning. Zinc phosphide induces bait shyness after its use for the first time, so it should not be repeated at least up to two months. It is prepared using following ingredients:

1 Flour of wheat or bajra or sorghum or rice or their mixture	: 935 g
2. Sugar powder	: 20 g
3. Edible vegetable oil	: 20 g
4. Zinc phosphide (80% technical powder)	: 25 g

Mix the above ingredients thoroughly in a container with a wooden stick and no house hold utensils should be used. The bait should be prepared afresh each time when required.

ii) Preparation of 0.005% bromadiolone bait: After ingestion of the lethal dose of 0.005% bromadiolone bait, the rats begin to die after 3 days and continue to die up to 15 days. Most of the rats die in their hide outs and thus great care is required to remove the carcasses from their hideouts which otherwise may create unhygienic conditions. Bromadiolone does not induce bait shyness and its bait can be placed for 3-5 days for satisfactory results. Also, its effect can be reduced by vitamin K in case of accidental poisoning. It is prepared using following ingredients:

1. Flour of wheat or bajra or sorghum or rice or their mixture	: 940 g
2. Sugar powder	: 20 g
3. Edible vegetable oil	: 20 g
4. Bromadiolone powder (0.25% technical powder)	: 20 g

Mix the above ingredients in a container with a wooden stick and no household utensils should be used.

b) Bait placement

The control of rodents in poultry farms with rodenticides must be safe to birds. The best possible safeguard during poison baiting in poultry farms is the use of protective bait boxes, preventing spillage of poison bait, its contamination in poultry feed and easy access to the rats while preventing its access to birds. Design of one such bait station for use in poultry farms is given in Fig 12. Placement of bait boxes on the runway of rats aligning to vertical surface yield good results since they are thigmotactic in behavior. Rodents exhibit neophobic responses to new objects including bait containers and poison baits. This makes them suspicious of anything introduced into their territories and as a result it may take a number of days before they are prepared to investigate such items.

Bait stations are simple containers that protect the bait from getting wet and help prevent access from children, pets, free-range poultry birds and untargeted wildlife. They can be acquired from any pest control supplier, hardware store, feed stores or they can be handmade using card board (Figure 13). The key to using bait stations is to place them in locations were rodents are likely to encounter them. Rodents prefer to run along the vertical structures so the bait station openings should be placed along the rodent's path. All bait stations need to be checked regularly to see if more bait is needed.

After poison baiting, dead rats should be removed immediately to avoid secondary toxicity as the hens may occasionally peck on dead rats and remove their hairs. Studies have shown that abundant availability of food from hoppers, eggs and chicks reduce the consumption of poison and mortality of rodents in poultry farms. Usually farmers also do not risk carrying out rodent control operations when the birds are in the premises. Therefore, the most appropriate time to implement rat control operations in the poultry house would be when the birds are vacated at the end of the flock cycle. Rodent control during this period is also very effective and carcasses of dead rats can be easily retrieved.

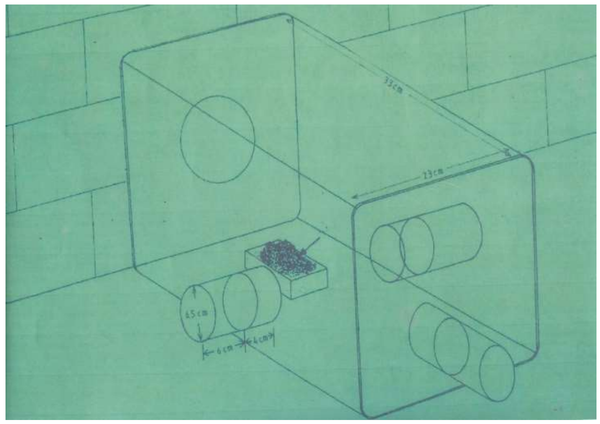

Fig. 12. Rodenticide bait station for use in poultry farms

Fig. 13. Rodenticide bait station made of card board

7. Biological control technique

The presence of cats in a poultry farm may act as a deterrent (Fig. 14). Being the predator of rodents, cats can limit low level rat or mouse populations. However, cats may introduce disease into a facility by bringing in rodents caught from crop fields.

Fig. 14. Cats as biocontrol agent outside the poultry house

8. Integrated rodent pest management

Integrated pest management is a strategy using various control techniques in an integral fashion, making maximum use of natural mortality factors and need based specific control measures. Thus, it is a system which in the context of the associated environment and the population dynamics of the pest species, utilizes all suitable techniques and methods in a compatible way.

Complete elimination of rodents with any single method is difficult. Therefore, integrated pest management approach should be adopted by using cultural, mechanical, chemical and biological techniques. Even after good sanitation and rodent proofing, some population may persist which can be tackled with other methods like trapping and rodenticide baiting. Some rodents after trapping may become trap-shy and similarly after control with acute rodenticide like zinc phosphide some rodents become bait-shy. They can be tackled by changing the method. Repeat treatment with the same rodenticide can be done by taking in account its mode of action and effects on the population. However, even after most thorough and complete control operation, few rodents continue to survive which often rebuild their population rapidly.

Control of rodents in poultry farms is never complete if the adjoining field areas and buildings are not included in the control operation. Despite of the significant advances in our knowledge of the biology of rodents, their problems in poultry farms continue to persist in serious proportions probably due to the lack of implementation of the available technologies. Rodent control has not yet become a regular practice of poultry farmers as a result they frequently suffer severe damage due to rats. The information summarized clearly reveals that techniques are now available which will give economical and effective rodent control in poultry farms.

SURVEY TECHNIQUES AND MONITORING OF RODENT POPULATION

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INTRODUCTION

Rodents are highly evolved mammals and important competitor with human for food and other resource. They are highly adaptive and can maintain high population level at any time. Therefore, it is essential for the ecologist and pest managers to have sufficient knowledge of rodent's habit and habitat, but expect for a few rodent species of economic importance there is a wide gap in information about them. Since rodents keep on shifting their habitat and acquiring newer situations, it becomes all the more important to monitor their species composition as well as density on a long-term basis. Estimates of rodent numbers should be taken up at selected sites in different parts of the country following a single methodology. If carried out on proper lines, it would be possible to predict population dynamics of individual species in the ecosystem or possible outbreak of pest rodent species.

SURVEY

It involves the general survey of existing species, their past history, and the factors of environment that influence them. The survey covers only the major points or places emphasis on the general aspects of species concerned and the environment.

RELATIVE AND ABSOLUTE ABUNDANCE

Abundance of a species can be designated as absolute and/or relative. Absolute abundance is the exact population present and is determined by numerical counts in per unit area. Relative abundance gives abundance in terms of related elements. It is reported in several ways such as rodents per trap night, hour or mile or by adjectives like common, rare and very common. The relative abundance is helpful in indicating proportionate populations i.e. frequency of occurrence such as once in a day, one in ten hours, 100 per ha. etc.

CENSUSES

Through census one can know status of population of any species in an area. For management and other research purposes census of species is a must. Thus, a census is a definite enumeration of any species population and is always reported in numerical terms.

It is rarely possible to count all the rodents of a given species (i.e. absolute nos.) even in small area; only relative nos. can be assessed by method of indirect census. Such methods are useful in comparison of population at different times i.e. in successive seasons, before or after control operation etc.

SAMPLING

It is very difficult to count population of species directly in a large area. In such cases method of sampling is very reasonable and practical in determining the population.

The most common sample plot is a quadrate, the size and shape of which depend upon the population and the area to be sampled. Hence for determining damage to various crops by rodents small quadrate of 1m2 can be used but for counting rodent burrows relatively larger quadrates of size 10 m2 or quadrate of unequal size i.e. extended quadrate of 5 m by 5 km can be used. The extended quadrate has the advantage of being a continuous area that touches many different cover type and aspects.

Another sampling method is transect, it is merely a line. In a crop field a diagonal transect is generally used to assess magnitude of infestation and crop damage. This method is convenient for quick sampling because it eliminates the necessity for laying out an area before sampling. This method is useful in large areas, remote regions and rough country.

POPULATION ESTIMATION

(a) Use of signs

(i) Tracking signs: Rodents leave traces of their presence in every habitat they occupy, such as, tracks in the grasslands, tooth marks in objects gnawed, feces, a greasy smear of skin secretion on smooth surfaces, foot prints on dusty floor, fresh loose earth etc. Census based track signs left is useful in urban environment and for one species only.

The method is useful for monitoring the household rodents. Before control known nos. of smears of any flour or talk powder are spread near study area. Next day smears having footprints or tail marks of rodents or with tracking of rodents are counted.

In Scotland changes in abundance of voles, Microtus agrestis, were recorded by the fresh fecal pellets. A wire frame was dropped at standard intervals in the area under study and number of fresh fecal pellets enclosed in the frame was counted. Such method can give relative abundance or rough indication the population.

(ii) Burrow count: In agricultural land and open fields the numbers of active burrows act as useful index of the rodent population. The burrows are plugged a day before and freshly opened burrows are counted next morning.

Further for diurnal rodents burrows are plugged in late evening and all the freshly opened burrows are counted next morning within thirty minutes of the start of rodent's activity on the surface, whereas, for nocturnal rodents burrows are plugged in afternoon and all the freshly opened burrows are counted in next morning.

Moreover, several species present in agricultural fields can be identified by their burrow opening and

(b) Census baiting

In special circumstances, food consumption can be used as an index of numbers. The highly acceptable food of known weight is kept at many points in the study area. After twenty-four hours, the food that remains is weighed and the bait points replenished. The procedure is repeated daily. Gradually the daily consumption increases, as the rodents become accustomed to new food. When the daily consumption become constant, the mean daily consumption for last three days may be used to provide an estimate of the minimum number of rodents present. Such calculation requires that experimenter should know the mean daily consumption of bait by species under study.

(c) Trapping

It is the most widely used method. It can be done in two ways.

(i) Capture, mark, release and recapture (CMR) method (Lincoln index): Traps are set in a grid pattern at an interval of fifteen meters. In an area of one hectare about forty-nine traps are needed. Traps containing bait should be left for 2-3 days in the field to overcome the neophobia of rodents and developing the habit of entering the traps. For effecting trapping the traps are set for one night and recollected next morning. All the trapped rodents are marked either by toe clipping or dyes and released. The second trapping could be taken up after one week. The second trapping may include some marked rodents of the first trapping. The size of population (Lincoln index) at the first trapping can now be calculated:

$$N = \frac{M.n}{m}$$

N= population size

M=number trapped in first trapping

n=total number trapped in second trapping

m=number re-trapped (marked) in second trapping

As an example, assume we captured 50 rats in some grain shops in two days, marked them and released them back into the shops (M). One week later we again trap for two days and capture 40 rats (n) out of which 10 were marked (m). The population is estimated as:

N=50x40/10=200

There were an estimated 200 rats in the original population in the grain shops. The confidence limits at the 95% level may be calculated from the standard error:

SE=√M2n(n-m)/m3

To determine the limits within which the population lies (95% confidence limits), add and subtract two standard errors from the estimate. Therefore, from our original estimate

SE=√(502x40) (40-10)/503 = 4.9x2 = 9.8 (rounded to 10)

Upper limits = 300 +10 = 300

Lower limits = 300-10= 290

(ii) The trap line method: The population is sampled by trapping on a trap line or lines across the area under study. Snap or Sherman traps can be used for setting such a trap line. Gap between subsequent traps is depending upon size or rodents, for the rodents of small size interval of five meters is sufficient, whereas, for larger rodents this interval should be ten to fifteen meters. A trap line should not run through more than one habitat, because different habitats are likely to harbour different densities of species studied.

To compare populations in different areas or seasons, a trap index (I) may be calculated:

$$I = \frac{M}{x.t}$$

Where x=number of traps used in trap line

t= number of nights during which traps were set

M= total number of animals trapped

For example, in a trapline of 100 traps set for 3 successive nights and catching 25 bandicoots, the trap success for the field sampled would be:

25/3x100 traps x 100 =8.33%

Generally, a figure of 10% catch indicates a high rodent population.

Some species enter traps more readily than others which are more cautious. This can be partly overcome by setting traps for at least three consecutive nights in the same place. This allows some of the trap-shy species to be caught after the bolder or more inquisitive species have been already trapped. There should be a fixed number of nights that the traplines are operated throughout the study.

RODENT MANAGEMENT CAMPAIGNS: ANDHRA PRADESH MODEL

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INTRODUCTION

Andhra Pradesh State in India has a proven history of periodic rodent outbreaks resulting in significant production loss of rice, pulses, sugarcane and coconut. The financial implications of yearly minimum losses come to around Rs.15,000 million (m.) in the case of rice production, Rs.300 m. in case of coconut and storage losses of another Rs.375 m. in the case of storage of rice alone. The losses will be more than the above in the years of outbreaks. Godavari delta districts, commonly known as rice bowl of Andhra Pradesh have become endemic for rodent problem due to Rice-Rice-Pulses cropping pattern due to continued availability of food and shelter for rodent pests. Deltaic alluvial soils which are bulky and soft found highly conducive for making burrows easily by the pest rodents. In addition, increased irrigation facilities created in the state also contributed to increased productivity thereby more rodent problem.

The lesser bandicoot, *Bandicota bengalensis* is the predominant and problematic species in rice cultivation in the State. An estimate made by All India Network Project on Vertebrate Pest Management (AINP on VPM-ICAR Project) working at AP Rice Research Institute, Acharya N.G. Ranga Agricultural University, Maruteru indicated the rodent damage to rice as 15.9% in West Godavari, 10.45% in East Godavari, 10.42% in Krishna and 8.34% in Guntur districts. The studies conducted by AINP on VPM indicated that an overall tiller damage to rice crop ranging from 9.56 to 60.8% during kharif and 0.42 to 30.9% in rabi crop. As per these reports and assuming a moderate loss of 10% in Rice due to rodent pests the production loss would be around 1.5 m. tones out of 15 m. tones of total production of the state every year. In coastal districts, coconut is cultivated around rice field bunds. The ICAR Project estimated the nut damage ranging from 10 to 15% of affected coconut palms. The infested palms are reported to be ranging from 40 to 60 per cent. Based on this available data the nut loss in coconut due to the rodent damage is around Rs.300 million in the state. In Sugarcane, cane damage ranging from 6.7 to 9.2% is reported in various studies.

The average land holding by farmers is 0.8 ha with 3.13 lakh small farmers and 0.77 lakh marginal farmers. These small and marginal farmers normally do not adopt any rodent control measures, until the rodent population reaches peak. The normal practices followed by farmers include bounty payment, trapping with indigenous bamboo traps, poison bait application, which often includes phorate. These measures are taken by farmers at individual level thereby covering small patches of the crops grown. Unreported mortality of non-target animals like buffalos, cows and birds also exist in these districts due to acute poisons and their improper use. Further, retention of the harvested crop produce for longer periods in the farmers' fields in stacks leads to more rodent damage. In some areas phorate is used for rodent control contrary to any scientific recommendation.

In view of the above situation, the Department of Agriculture organizes rodent control with chemical measures through campaign approach involving the farming community.

1. Rodent Control Campaigns in the State

Campaign approach of rodent control was initiated in the state during the rodent outbreak of Godavari Krishna delta districts during Rabi 1996-97 using aluminium phosphide pellets. However, in view of the possible hazards posed by this fumigant and based on the national recommendations of Expert Committee on Rodent Control of Government of India, anticoagulant rodenticide replaced the aluminium phosphide fumigation. In view of reported rodent damage at higher level in the Godavari-Krishna delta districts, rodent control campaigns were initiated using anticoagulant rodenticide baits from Rabi 2003-04. From that year onwards rodent control campaigns have become regular in these districts because of identified increased productivity in rice.

The details of rodent control campaigns organized for the past 2 years in rice crop in West Godavari Dist.:

S.N.	Year / No. of districts covered	Name of the district	Area treated (lakh ha)	% Rodent Control (in terms of reduction in tiller damage)
1	2017 (Kharif)	West Godavari	1,99,729	74.0
2	2018 (Kharif)	West Godavari	1,99,729	72.2

2. Guidelines for organizing the rodent control campaigns in the State

The following guidelines are considered to be adopted by the field extension functionaries for successful results in rodent control.

1. Technical guidelines

a) In each district, the rodent control campaigns are to be started in villages with known rodent problem and suitable dates are to be stipulated and the schedule should be implemented in all those villages on the stipulated dates without fail.

b) Poison baits should be prepared preferably at a common place in the village in stipulated time and made available to the farmers at that place.
c) Farmers should contribute the bait material and meet the operational costs.
d) Poison baits should be distributed to all the farmers as per the area requirement.
e) The rodenticide treatment has to be covered in the cropped area, including common sites, roads, canals, drain bunds, porambokes, waste lands etc. Simultaneous treatment has to be taken up in all the areas.
f) The Gram Panchayat should bear the cost of bait material and operational charges required to treat the waste lands and other Government lands etc (no man lands).
g) The programme has to be organized on community approach keeping village as a unit.
h) Co-ordinate and motivate all institutional agencies at village level for this massive Rodent Control Campaign.

Action plan:

(1) DAY – 1 Close all the burrows in the fields, field bunds, porambokes, canal bunds railway tracks, Roads, Barren lands etc.
(2) DAY – 2 Count the re-opened burrows and treat the burrows with Bromadiolone (0.005%) bait packets @ 10 g/burrow.
(3) DAY – 10 Observe the re-opened burrows and repeat step 2.
(4) DAY – 15 Observe the re-opened burrows and evaluate success of control through burrow count and damage index methods.

NOTE:

a) Care should be taken while handling Bromadiolone CB to avoid toxicity to non target animals.
b) Evaluation of rodent control success should be done.
c) The list of farmer beneficiaries may be prepared on the day of poison bait distribution and exhibited at Gram Panchayat Office.
d) The stocks will be made available at Sub-Divisional Asst. Director of Agriculture's Office and will be distributed to farmers by the Agricultural Officer / Agrl. Extension Officer on acknowledgement, at free of cost on filing the application form prescribed.
e) Rodent surveillance should be done through burrow count and damage appraisal methods.
f) Stocks of the Antidote for Bromadiolone - vitamin K1 – may be ensured with pharmacists.

2. **Administrative guidelines**
   Establishment of village level committees

For proper implementation of the rodent campaign at village level, a committee may be formed with the following members.

1. Gram Sarpanch.
2. Village Administrative Officer.
3. M.P.T.C. Member.
4. Progressive Farmer.
5. Adarsha Rythulu.
6. R.M.G. Members.

Accounting procedure to be followed:

1. The distribution of Rodenticides under free of cost / 100% subsidy should be done according to the instructions laid down in the Agrl. Department manual.
2. A separate stock Register should be maintained for this purpose at Asst. Director of Agriculture's office and necessary stock entries should be made on receipt from the supplying firm and the stocks should be given to the concerned Agricultural Officers under proper acknowledgement in the first instance.

3. Publicity and Propaganda

1. Wide publicity should be given about Rodent Control Programme by tom-tom and mass-media, by distribution of handouts, pamphlets and through farmers meetings at village level. The Agricultural Officer should appraise of the programme to Gram Sarpanch, M.P.P. President and MPTC Members.
2. The concerned Asst. Director of Agriculture are requested to appraise the programme to the local MLAs, MPs, MPP Presidents and Z.P.T.C. Members about the impact of the programme and request for their participation for successful implementation of the programme.
3. The Agricultural Officers and Asst. Directors of Agriculture concerned will personally held responsible for the proper organization and distribution of Rodenticides.
4. The Asst. Directors of Agriculture are requested to contact the other sister departments like Revenue, Panchayat Raj and other voluntary organizations for proper implementation of the programme.
5. The Asst. Directors of Agriculture are requested to take this item of work with special care and interest in time for successful implementation with proper evaluation.
6. The district officers are requested to send the particulars of area covered under Rodent Control Campaign and success achieved along with data on burrow number and crop loss before and after the campaign to Rodent Specialist, NPPTI, Rajendranagar for technical analysis.

The progress report of rodent control campaign mandal wise may be informed to this office in the following two proforma.

PROFORMA-I

Sl.No.	Mandal	Total paddy area sown (ha.)	Area treated with rodenticide in ha. (cropped area and no man lands).	No. of Live Burrows		
				Before treatment	After treatment	% control success
1	2	3	4	5	6	7

% Tiller Damage			Productivity (Kgs/ha.) (as per CC experiments).	Remarks
Before treatment	After treatment	% control success		
8	9	10	11	

PROFORMA-II

Sl.No.	Mandal	No. of Revenue villages and hamlets covered.	Area treated with Bromodialone chemical.	Quantity of chemical used.	Expenditure incurred on chemical (No.)	No. of posters supplied.
1	2	3	4	5	6	7

Expenditure incurred (Rs.)	No. of pamphlets supplied.	Expenditure incurred (Rs.)	Expenditure incurred on Publicity & Propaganda.	Total expenditure	Remarks.
8	9	10	11	12	13

4. **Observations to be taken by the Observer**

The following observations may be taken by the observers during their visit to districts:

Particulars of circulars issued from JDA office on schedule and guidelines

Circular no. and date	No. of proposed villages	Area	Dates

Stock and issue situation at JDA office

Name of the supplier	Quantity allotted to the District	Quantity received	Quantity delivered	Remarks

Stock and issue at ADA point of visit

Name of the Sub Division	Quantity allotted	Quantity received	Quantity issued till date	Stock available

Chemical issued to the villages on the day of visit

Date	Village	Chemical used	Bait material contributed	Farmers benefitted

Availability of antidote in nearby pharmacy

Name of Sub Division	No. of pharmacy points where antidote vitamin K1 is available

Rodent infestation in the areas of visit

Name of villages visited	Rodent infestation (burrows/He)	Rodent infestation (% Damage incidence)	Rodent infestation after last campaign	Remarks (Rodent infestation observation)

The visiting member may take one observation of infestation level (burrow count) at each village at one randomly selected plot and the same may be given in remarks

4. Checklist

a) Particulars of circulars issued from JDA office on schedule and guidelines
b) Stock and issue situation at JDA office
c) Stock and issue at ADA point of visit
d) Chemical issued to the villages on the day of visit
e) Availability of antidote in nearby pharmacy
f) Rodent infestation in the areas of visit
g) List of beneficiaries displayed at panchayat offices
h) Procedure of bait preparation at community point
i) Issue of bait packets to the farmer beneficiaries
j) Suggestions received from the farmers/committees
k) Any difficulties faced during the campaign
l) Any other observations and impressions

5. Terms of Reference

The following Terms of Reference could be followed by the Supervisory Officers overseeing the anti-rodent campaigns:

- To verify of receipts of the rodenticide, its stock and necessary entries in the stock registers – at District level and visiting Mandals
- To verify letters issued to the ADA/AOs on the schedule of campaigns in identified villages with guidelines to follow
- To verify formation of village committees of visiting villages and lists of beneficiary farmers put up at public display
- To interact with local farming community including Sarpanches of the campaign villages
- To check the method of bait preparation at community level and issue of the prepared bait material to the beneficiaries

Stages in community rodent control campaings using rodenticide poison baits

Identifcation of live rodent burrows

Prepartion of rodenticide poison bait

Packeting of poison bait

Pocketing of poison bait packets

WILDLIFE (PROTECTION) ACT, 1972

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HISTORY OF WILDLIFE (PROTECTION) ACT, 1972

On 21st August 1972, the Wildlife Protection Act was passed. This act was later implemented on 9th September 1972.

Laws related to wildlife have been a part of our history, long before the Wildlife Protection Act was passed. The need to protect our wildlife has come from the awareness to restore the crucial ecological balance in nature, least it results in a catastrophe produced by humans, which will inflict nature and ultimately humans. The oldest law to protect wildlife and nature can be found in the 3rd century BC when Ashoka, the king of Magadha put in place a law to preserve wildlife and environment.

The first codified law for the protection of wildlife was introduced by the British in 1887, which enacted the Wild Birds Protection Act 1887. The British Government used this act to formulate rules forbidding the possession and sale of any wild birds which may have been captured or killed during the breeding season. In 1912, the British again passed a new law called the Wild Birds and Animals Protection Act 1912, which in the long run was unable to protect the wild birds and animals. In 1935, the act of 1912 was amended by the Wild Birds and Animals Protection (Amendment) Act 1935.

The struggle for Independence saw the issue of wildlife protection shifted to the back burner, but shortly after Independence the Constituent Assembly placed "Protection of Wild Birds and Wild Animals" in the state list and the state legislature was given power to legislate. It was ultimately not until 1960 that the issue of diminishing wildlife came to the forefront again.

The Wildlife Protection Act of 1972 is essentially an Indian Legislation executed by the Indian Parliament for the protection of various species of plants and animals. Before this act was passed India only had five designated national parks and the coming of this act saw the establishment of protected plant and animal species and poaching and harvesting in these areas were strictly prohibited and considered illegal.

This act makes a provision for the protection of wild animals, birds and plants and this act applies to all parts of India, except Jammu and Kashmir, which has its own wildlife act. The Wildlife Protection Act is divided under six schedules which provide different degrees of protection. Schedule 1 and part 2 of Schedule 2 provide complete protection and any violation under these calls for the highest punishment. Species mentioned in Schedule 3 and 4 are also protected, but the penalty associated with violation is much less. Schedule 5 includes animals which may be hunted and plants listed under Schedule 6 are forbidden from being cultivated or planted.

The Wildlife Protection Act of 1972 prohibits the capturing, killing, poisoning or trapping of wild animals. This act also includes injuring, destroying and removing any part of a wild animal's body. In the case of wild birds and reptiles, the act forbids disturbing or damaging their eggs. The act is also against Taxidermy, which is the preservation of a dead wild animal as a trophy, or in the form of rugs, preserved skins, antlers, horns, eggs, teeth and nails.

Penalties for any violation under any Schedule can be carried out by agencies like the Police, The Central Bureau of Investigation, The Forest Department and the Customs. Charge sheets are filed by The Forest Department and other agencies who encounter violators usually hand over the case to the Forest Department.

In 2002 an amendment in the Wildlife Protection Act of 1972 was made. This act was known as the Wildlife (Protection) Amendment Act 2002. This amendment came into force in January 2003 and under it, punishment for defaulters is harsher. Under this amendment if one is caught in the process of trade of animal trophies and other articles derived from wild animals they will be subject to three years of imprisonment and/or a fine of Rs. 25,000.

As of April 2012, India today has 102 national parks and 166 more have been authorized. These protected areas provide a safe and natural environment for wild animals and birds to live safely in their natural habitat without the fear of being hunted or poached.

The Wildlife Protection Act, 1972 is an Act of the Parliament of India enacted for protection of plants and animal species. Before 1972, India had only five designated national parks. Among other reforms, the Act established schedules of protected plant and animal species; hunting or harvesting these species was largely outlawed. The Act provides for the protection of wild animals, birds and plants; and for matters connected there with or ancillary or incidental thereto. It extends to the whole of India. It has six schedules which give varying degrees of protection. Schedule I and part II of Schedule II provide absolute protection -

offences under these are prescribed the highest penalties. Species listed in Schedule III and Schedule IV are also protected, but the penalties are much lower. Schedule V includes the animals which may be hunted. The specified endemic plants in Schedule VI are prohibited from cultivation and planting. The hunting to the Enforcement authorities have the power to compound offences under this Schedule (i.e. they impose fines on the offenders). Up to April 2010 there have been 16 convictions under this act relating to the death of tigers.

DEFINITIONS UNDER THE ACT (SECTION 2)

"animal" includes amphibians, birds, mammals, and reptiles, and their young ones, and also includes, in the cases of birds and reptiles, their eggs.

"animal article" means an article made from any captive or wild animal, other than vermin, and includes an article or object in which the whole or any part of such animal has been used and an article made therefrom.

"hunting" includes

(a) capturing, killing, poisoning, snaring, or trapping any wild animal, and every attempt to do so

(b) driving any wild animal for any of the purposes specified in sub clause

(c) injuring, destroying or taking any body part of any such animal, or in the case of wild birds or reptiles, disturbing or damaging the eggs or nests of such birds or reptiles.

"taxidermy" means the curing, preparation or preservation of trophies.

"trophy" means the whole or any part of any captive or wild animal (other than vermin) which has been kept or preserved by any means, whether artificial or natural. This includes:

(a) rugs, skins, and specimens of such animals mounted in whole or in part through a process of taxidermy

(b) antler, horn, rhinoceros horn, feather, nail, tooth, musk, eggs, and nests and shells.

"uncured trophy" means the whole or any part of any captive animal (other than vermin) which has not undergone a process of taxidermy. This includes a freshly killed wild animal, ambergris, musk and other animal products.

"vermin" means any wild animal specified in Schedule V.

"wildlife" includes any animal, bees, butterflies, crustacean, fish and moths; and aquatic or land vegetation which forms part of any habitat

HUNTING (SECTION 9)

This section describes what constitutes hunting and the intent to hunt. Hunting wild animals is prohibited.

OWNERSHIP (SECTION 40 & 42)

Regarding ownership issues and trade licenses. Ownership will be not transferred to another party also regarding issues to trade license.

PENALTIES (SECTION 51)

Penalties are predescribed in section 51. Enforcement can be performed by agencies such as the Forest Department, the Police, the Wildlife Crime Control Bureau (WCCB), the Customs and the Central Bureau of Investigation (CBI). Charge sheets can be filed directly by the Forest Department. Other enforcement agencies, often due to the lack of technical expertise, hand over cases to the Forest Department.

AMENDMENTS

The Code has been amended several times. Here is the list with year of amendments:

Wild Life (Protection) Amendment Act 1982

Wild Life (Protection) Amendment Act 1986

Wild Life (Protection) Amendment Act 1991

Wild Life (Protection) Amendment Act 1993

Wild Life (Protection) Amendment Act, 2002

Wild Life (Protection) Amendment Act 2006

Wild Life (Protection) Amendment Act 2013

2002 AMENDMENT

The 2002 Amendment Act which came into force in January, 2003 have made punishment and penalty for offences under the Act more stringent.

Offence

For offences relating to wild animals (or their parts and products) included in schedule-I or part II of Schedule- II and those relating to hunting or altering the boundaries of a sanctuary or national park the punishment and penalty have been enhanced, the minimum imprisonment prescribed is three years which may extend to seven years, with a minimum fine of Rs. 10,000/-. For a subsequent offence of this nature, the term of imprisonment shall not be less than three years but may extend to seven years with a minimum fine of Rs. 25,000. Also a new section (51 - A) has been inserted in the Act, making certain conditions applicable while granting bail: 'When any person accused of the commission of any offence relating to Schedule I or Part II of Schedule II or offences relating to hunting inside the boundaries of National Park or Wildlife Sanctuary or altering the boundaries of such parks and sanctuaries, is arrested under the provisions of the Act, then not withstanding anything contained in the Code of Criminal Procedure, 1973, no such person who had been previously convicted of an offence under this Act shall be released on bail unless -

(a) The Public Prosecutor has been given an opportunity of opposing the release on bail; and (b) Where the Public Prosecutor opposes the application, the Court is satisfied that there are reasonable grounds for believing that he is not guilty of such offences and that he is not likely to commit any offence while on bail".

In order to improve the intelligence gathering in wildlife crime, the existing provision for rewarding the informers has been increased from 20% of the fine and composition money respectively to 50% in each case. In addition to this, a reward up to Rs. 10,000/- is also proposed to be given to the informants and others who provide assistance in detection of crime and apprehension of the offender.

At present, persons having ownership certificate in respect of Schedule I and Part II of Schedule II animals, can sell or gift such articles. This has been amended with a view to curb illegal trade, and thus no person can now acquire Schedule I or Part II of Schedule II animals, articles or trophies except by way of inheritance (except live elephants).

Stringent measures have also been proposed to forfeit the properties of hardcore criminals who have already been convicted in the past for heinous wildlife crimes. These provisions are similar to the provisions of 'Narcotic Drugs and Psychotropic Substances Act, 1985'. Provisions have also been made empowering officials to evict encroachments from Protected Areas.

Offences not pertaining to hunting of endangered species

Offences related to trade and commerce in trophies, animals' articles etc. derived from certain animals (exception: chapter V A and section 38J) attracts a term of imprisonment up to three years and/or a fine up to Rs. 25,000/-.

Section 51. Penalties

(1) Any person who 1[contravenes any provision of this Act 2[(except Chapter VA and section 38J)] or any rule or order made there-under or who commits a

breach of any of the conditions of any license or permit granted under this Act, shall be guilty of an offence against this Act, and shall, on conviction, be punishable with imprisonment for a term which may extend to 3[three years] or with fine which may extend to 4[twenty-five thousand rupees] or with both: 5[Provided that where the offence committed is in relation to any animal specified in Schedule I or Part II of Schedule II or meat of any such animal or animal article, trophy or uncured trophy derived from such animal or where the offence relates to hunting in a sanctuary or a National Park or altering the boundaries of a sanctuary or a National Park, such offence shall be punishable with imprisonment for a term which shall not be less than three years but may extend to seven years and also with fine which shall not be less than ten thousand rupees: Provided further that in the case of a second or subsequent offence of the nature mentioned in this sub-section, the term of imprisonment shall not be less than three years but may extend to seven years and also with fine which shall not be less than twenty-five thousand rupees.] 6[(1A) Any person who contravenes any provisions of Chapter VA, shall be punishable with imprisonment for a term which shall not be less than 7[three years] but which may extend to seven years and also with fine which shall not be less than 8[ten thousand rupees].] 9[(1B) Any person who contravenes the provisions of section 38J shall be punishable with imprisonment for a term which may extend to six months, or with fine which may extend to two thousand rupees, or with both: Provided that in the case of a second or subsequent offence the term of imprisonment may extend to one year, or with fine which may extend to five thousand rupees.] 10[(1C) Any person, who commits an offence in relation to the core area of a tiger reserve or where the offence relate to hunting in the tiger reserve or altering the boundaries of the tiger reserve, such offence shall be punishable on first conviction with imprisonment for a term which shall not be less than three years but may extend to seven years, and also with fine which shall not be less than fifty thousand rupees but may extend to two lakh rupees; and in the event of a second or subsequent conviction with imprisonment for a term of not less than seven years and also with fine which shall not be less than five lakh rupees but may extend to fifty lakh rupees.

(1D) Whoever abets any offence punishable under sub-section (1C) shall, if the act abetted is committed in consequence of the abetment, be punishable with the punishment provided for that offence.]

(2) When any person is convicted of an offence against this Act, the court trying the offence may order that any captive animal, wild animal, animal article, trophy, 11[uncured trophy, meat, ivory imported into India or an article made from such ivory, any specified plant, or part or derivative thereof] in respect of which the offence has been committed, and any trap, tool, vehicle, vessel or

weapon, used in the commission of the said offence be forfeited to the State Government and that any license or permit, held by such person under the provisions of this Act, be cancelled.

(3) Such cancellation of license or permit or such forfeiture shall be in addition to any other punishment that may be awarded for such offence.

(4) Where any person is convicted of an offence against this Act, the court may direct that the license, if any, granted to such person under the Arms Act, 1959 (54 of 1954), for possession of any arm with which an offence against this Act has been committed, shall be cancelled and that such person shall not be eligible for a license under the Arms Act, 1959 (54 of 1959), for a period of five years from the date of conviction. 12[(5) Nothing contained in section 360 of the Code of Criminal Procedure, 1973 (2 of 1974) or in the Probation of Offenders Act, 1958 (20 of 1958) shall apply to a person convicted of an offence with respect to hunting in a sanctuary or a National Park or of an offence against any provision of Chapter VA unless such person is under eighteen years of age.]

SUMMARY

The Wildlife Protection Act, 1972, provides for protection to listed species of flora and fauna and establishes a network of ecologically-important protected areas. The Act consists of 60 Sections and VI Schedules- divided into Eight Chapters. The Wildlife Protection Act, 1972 empowers the central and state governments to declare any area a wildlife sanctuary, national park, conservation reserve and community reserve. There is a blanket ban on carrying out any industrial activity inside these protected areas. It provides for authorities to administer and implement the Act; regulate the hunting of wild animals; protect specified plants, sanctuaries, national parks and closed areas; restrict trade or commerce in wild animals or animal articles; and miscellaneous matters. The Act prohibits hunting of animals except with permission of authorized officer when an animal has become dangerous to human life or property or as disabled or diseased as to be beyond recovery.

The Act underwent many amendments. An amendment to the Act in 1982, introduced provisions permitting the capture and transportation of wild animals for the scientific management of animal population. An amendment in the year 1991 resulted in the insertion of the special chapters dealing with the protection of specified plants and the regulation of zoos. This also recognized the needs of tribal and forest dwellers and changes were introduced to advance their welfare. The near-total prohibition on hunting was made more effective by the Amendment Act of 1991.

Widespread changes have been made by the Wildlife (Protection) Amendment Act, 2002 and a new chapter has been incorporated as Chapter VI-A to deal with the forfeiture of property derived from illegal hunting and trade. Further, this amendment Act also introduced the concept of co-operative management through conservation reserve management committee and community reserve committees.

With this introduction now let us discuss the Wildlife (Protection) Act, 1972 in a detailed way.

EVOLUTION AND DEVELOPMENT OF THE CONCEPT OF WILDLIFE PROTECTION IN INDIA

India is endowed with an immense variety of natural resources in its rich animal and plant heritage. Wildlife is one of our basic and natural resources that satisfies the needs or wants of civilization. Therefore, this resource must be conserved, preserved and protected for the existence of mankind. Now let us see the chronological development of wildlife protection in India in different periods.

1. Wildlife Protection in Ancient India: In ancient India the environmental protection was a moral duty which is imposed on people by religious scriptures, seers, and other agencies. The scriptures of Hindu religion emphasize the protection of the environment and the living creatures. Some of the animals were considered as the vehicles of gods. Matsya was considered as the go since it is the first living organism existed in earth. Cow was considered as god. Certain birds and animals were considered as the vehicle of gods. Certain trees like Banyan, Tulsi etc. were considered as the dwelling place of the gods. Kautilya, one of the great political philosophers and the author of The Arthasasthra, prohibited and prescribed penalties for the killing of animals, cutting of trees and the excess exploitation of the natural resources. The great Maurya king Ashoka banned the killing of wild animals, and later prohibited the killing of certain species of animals.

In the words of St. Thukharam, animals and plants are the kin and kith of human beings. These are some specimens to show the manner in which the ancient Indians took care for the protection of wildlife. Though it was a moral duty in the beginning later the kings started to impose it as a legal duty. In ancient India, as the moral duty, the destruction of heritage and richness of environment and the biodiversity was considered as an injury and insult to Gods. And now the wildlife protection is a legal duty.

2. Wildlife Protection in India during British period: In the pre-constitutional period, there were a few legislations which are enacted to protect the wildlife from exploitation. The Cattle Trespass Act, 1871; The Elephants Preservation Act, 1879; some sections of Indian Penal Code, 1860; wild Birds and Animals Protection Act, 1912, The Indian Forest Act, 1927 are some pre-constitutional enactments on wildlife protection.

The Elephants Preservation Act prohibited killing, injuring or capturing, or any attempt at the same, unless it is in self-defense, permitted by a license, or when the elephant is found damaging house or cultivation, or immediate vicinity of public road, railway or canal. The Indian Penal Code, 1860, though it has no specific provision relating to wildlife, but it defines the term animal in Section 47 and declares maiming, killing of animals as an offence and punishable under Sections 428 and 429.

The Indian Forest Act, 1927 also included certain provisions for restricting hunting in reserved and protected forests and other authorized establishments or Sanctuaries. Under this Act, hunting, shooting, fishing, poisoning water or setting traps, etc. is an offence. These are the some of the wildlife protection legislations enacted in the British period.

3. Wildlife Protection in India after Independence: The Post- independence era witnessed a lot of changes in the policies and attitudes of the Governments with respect to environmental protection. There were many enactments to protect the Forest, Environment, Water, Air and Bio-Diversity. All these Acts are directly or indirectly giving provisions to the protection of the wildlife. But let me specifically emphasis on Wildlife protection, since my topic is wildlife protection.

The Indian Constitution gives ample provisions to protect the wildlife in its territory. Though there are many implied provisions on wildlife protection in the constitution like Art.21, Union, State and Concurrent list, the main Articles which specifically protects the wildlife are Art.48-A and Art. 51-A(g). Art. 48-A says that the state shall endeavour to protect and improve the environment and to safeguard the forest and wildlife of the country. Art. 51A (g) imposes fundamental duty on every citizen of India to protect and improve the environment and have compassion for living creatures.

The Wildlife Protection Act, 1972 is the major legislation which specifically enacted for the protection of the wildlife in India. We will discuss this Act in detail in the following pages. Besides this, there are much legislation enacted for the protection and preservation of the wild life. Let us see them in a glance. They are The Wildlife Protection Act, 1972; The Wild Life (Transactions and Taxidermy) Rules, 1973; The Wild Life (Stock Declaration) Central Rules, 1973; The Wild life (Protection) Licensing (Additional Matters for

Consideration) Rules, 1983; The Wild Life (Protection) Rules, 1995; The Wild Life (Specified Plants - Conditions for Possession by Licensee) Rules, 1995; Forest Conservation Act, 1980; Forest (Conservation) Rules, 1981; National Forest Policy, 1988; Biological Diversity Act, 2002; Besides these Acts, there are many legislations on Air, Water, Environment, Hazardous substance management, Solid waste management, Noise Pollution prevention, and so on. Such laws also have the provisions to protect the wildlife.

In 1973, a centrally sponsored scheme Project Tiger was launched to ensure the maintenance of the population of tigers in India. In 1991-92, The Project Elephant was launched aiming at ensuring long term survival of identified viable population of Elephants and tackling the problematic decrease of the elephant population. This is the comprehensive description on the evolution and development of wildlife protection in India. Now let me to explain the Wildlife (Protection) Act, 1972 in a detailed way. The major provisions of the Wildlife (Protection) Act, 1972 are as following.

TERRITORIAL JURISDICTION OF WILDLIFE (PROTECTION) ACT, 1972

Wildlife (Protection) Act, 1972 has been accepted and adopted by all the states except Jammu and Kashmir, though the recent development after abolition of Section 370 from Jammu & Kashmir, makes accepted and adopted there too. This is the first comprehensive legislation relating to protection of wild life was passed by the Parliament and it was assented by the President on 9th September, 1972 and came to be known as The Wild Life (Protection) Act, 1972 (53 of 1972).

DEFINITION OF WILDLIFE

The Section 2(37) of the Act defines wildlife as wildlife includes any animal, bees' butterflies, crustacean, fish and moths; and aquatic or land vegetation which forms part of any habitat. So, the meaning of the wildlife in this Act is very wide and inclusive of all kinds of flora and fauna.

AUTHORITIES CONSTITUTED UNDER WILDLIFE (PROTECTION) ACT

As per the Sec. 3 of the Act, the Central Government may appoint a Director of Wildlife Preservation, Assistant Directors of Wildlife Preservation and such other officers and employees as may be necessary. As per the Sec. 4, the State Government may, for the purpose of this Act, appoint Chief Wildlife Warden, Wildlife Warden, Honorary Wildlife Wardens and other officers and employees as may be necessary. As per Sec. 6, the State Governments and the Administrators in Union Territories shall constitute a Wildlife Advisory Board.

THE WILDLIFE ADVISORY BOARD (SEC. 6)

The Sec. 6 of this Act enforces and enables the state governments and the administrators of the Union Territories to constitute a Wildlife Advisory Board in each states and union territories.

1. The members of the Wildlife Advisory Board

It shall consist of the Minister in charge of Forests in the State or Union territory as the Chairman. If there is no such minister, then the Chief Secretary will be the Chairman of the Board. The other members are, two members of the State Legislature or Legislature of Union Territory; Secretary to the state government or the government of the union territory, in charge of forests; the Forest officer in charge of the State Forest Department; an officer nominated by the Director of Wildlife Preservation; Chief wildlife warden; officers of the state government not exceeding 5; and such other persons, not exceeding 10, who in the opinion of the state government, are interested in the protection of wildlife, including the representatives of tribals not exceeding 3.

2. Duties of Wildlife Advisory Board (Sec. 8)

The Wildlife Advisory Board mainly constituted to advise the state government in the following matters.

a) In the selection of areas to be declared as Sanctuaries, National Parks and Closed areas and the administration thereof;

b) In formulation of the policy for protection and conservation of wildlife and specified plants;

c) In any matter relating to the amendment of any schedule;

d) In relation to the measure to be taken for harmonizing the needs of the tribals and other dwellers of the forests with the protection and conservation of wildlife;

e) In any other matter connected with the protection of wildlife which may be referred to it by the state government.

HUNTING OF WILD ANIMALS (SEC. 9)

Sec. 2(16(a) (b) (c)) defines the word hunting as follows Hunting, with its grammatical variations and cognate expressions, includes; capturing, killing, poisoning, snaring, and trapping or any wild animal and every attempt to do so; driving any wild animal for any of purposes specified in sub clause; injuring or destroying or taking any part of the body of any such animal, or in the case of wild birds or reptiles, damaging the eggs of such birds or reptiles, or disturbing the eggs or nests of such birds or reptiles;

Sec. 9 of the Act prohibits hunting of any wild animal specified in Schedules 1, 2, 3, and 4. Any person who hunts any wild animal shall be punishable with imprisonment for a term which may extend to 3 years or with fine which may extend to Rs. 25000/- or with both. However, if any person commits the offence in the sanctuary or national park, with respect any animal specified in Schedule 1, he shall be punishable with imprisonment which shall not be less than 1 year but may extend to 6 years and also with fine which shall not be less than 5000/-.

1. Hunting of Wild animals to be permitted in certain cases

The Chief Wildlife Warden may permit hunting of wild animals in certain situations. They are;

(a) The Chief Wildlife Warden may, if he is satisfied that any wild animal specified in Schedule 1 has become dangerous to human life or is so disabled or diseased as to be beyond recovery, by order in writing and stating the reasons therefore, permit any person to hunt such animal or cause animal to be hunted;

(b) The Chief Wildlife Warden or the authorized officer may, if he is satisfied that any wild animal specified in Schedule. II or III or IV has become dangerous to human life or to property (including standing crops on any land) or is so disabled or diseased as to be beyond recovery, by order in writing and stating the reasons therefore, permit any person to hunt such animal or cause such animal to be hunted.

(c) The killing or wounding in good faith of any wild animal in defense of oneself or of any other person shall not be an offence; Provided that nothing in this sub-section shall exonerate any person who, when such defense becomes necessary, was committing any act in contravention of any provision of this Act or any rule or order made there under.

(d) Any wild animal killed or wounded in defense of any person shall be Government property.

2. Grant of permission for hunting for special purposes

The Chief Wildlife Warden, permit, by an order in writing stating the reasons therefore, to any person, on payment of such fee as may be prescribed, which shall entitle the holder of such permit to hunt, subject to such conditions as may be specified therein, any wild animal specified in such permit, for the purpose of,

(a) Education;

(b) Scientific research;

(c) Scientific management; means and includes
(i) translocation of any wild animal to an alternative suitable habitat; or
(ii) population management of wildlife, without killing or poisoning or destroying any wild animals.

(d) Collection of specimens
(i) for recognised zoos subject to the permission under section 38-1 or
(ii) for museums and similar institutions;

(e) derivation, collection or preparation of snake-venom for the manufacture of life saving drugs

PROTECTION OF SPECIFIED PLANTS

Sec. 17A of the Act prohibits picking, uprooting, etc., of specified plants. as otherwise provided in this Chapter, no person shall:

(a) willfully pick, uproot, damage destroy, acquire or collect any specified plant from any forestland and area specified, by notification, by the Central Government,

(b) possess, sell, other for sale, or transfer by way of gift or otherwise, or transport any specified plant, whether alive or dead, or part or derivative thereof: Provided that nothing in this section shall prevent a member of a scheduled tribe, subject to the provisions of Chapter IV, from picking, collecting or possessing in the district he resides any specified plant or part or derivative thereof for his bonafide personal use.

The Chief Wild Life Warden may with the previous permission of the State Government, grant to any person a permit to pick, uproot, acquire or collect from a forest land or the area specified under section 17A or transport, subject to such conditions as may be specified therein, any specified plant for the purpose of education; scientific research., collection, preservation and display in a herbarium of any scientific institutions; or propagation by a person or an institution approved by the Central Government in this regard.

SANCTUARIES

Section 18 provides that the State Government may, by notification, declare its intention to constitute any area other than area comprised with any reserve forest or the territorial waters as a sanctuary if it considers that such area is of adequate ecological, faunal, floral, geo-morphological, natural or zoological significance, for the purpose of protecting, propagating or developing wildlife or its environment. For the purposes of this section, it shall be sufficient to describe the area by roads, rivers, ridges, or other well-known or readily intelligible boundaries.

The Chief Wildlife Warden may, on an application, grant to any person a permit to enter or reside in a sanctuary for the following purposes;

a) Investigation or study of wildlife and any purpose ancillary or incidental thereto;
b) Photography
c) Scientific research
d) Tourism
e) Transaction of lawful business with any person in the sanctuary

Only a public servant on duty or permit holder or a person having a right over immovable property within the limits of a sanctuary, person passing through pathway in the sanctuary and dependants of the above can also enter or reside in the sanctuary.

NATIONAL PARKS

The state government, for the purpose of protecting, propagating or developing wildlife may by a notification declare that an area, by reason of its ecological, faunal, floral, geo-morphological or zoological association or importance, needed to be constituted as a National Park. Once a National Park is declared, no alteration of the boundaries shall be made except on the resolution passed by the legislature of the state. In a National Park, the following activities are strictly prohibited;

a) Destroying, exploring or removing any wildlife,
b) Destroying, damaging the habitat of any wild animal,
c) Deprive any wild animal of its habitat,
d) Grazing of any livestock

CENTRAL ZOO AUTHORITY AND RECOGNITION OF ZOOS

The central government shall constitute the Central Zoo Authority, consisting of a chair person, tem members and a member secretary. They shall hold office for a period of three years. The Central Zoo Authority shall perform the following functions:

(a) Specify the minimum standards for housing, unkeep and veterinary care of the animals kept in a zoo;

(b) Evaluate and assess the functioning of zoos with respect to the standards or the norms as may be prescribed;
(c) Recognize or derecognize zoos;
(d) Identify endangered species of wild animals for purposes of captive breeding and assigning responsibility in this regard to a zoo;
(e) Co-ordinate the acquisition, exchange and loaning of animals for breeding purposes;
(f) Ensure maintenance of stud-books of endangered species of wild animals bred in captivity;
(g) Identify priorities and themes with regard to display of captive animals in a zoo;
(h) Co-ordinate training of zoo personnel in India and outside India;
(i) Co-ordinate research in captive breeding and educational programmes for the purposes of zoos;
(j) Provide technical and other assistance to zoos for their proper management and development on scientific lines;
(k) Perform such other functions as may be necessary to carry out the purposes of this Act with regard to zoos.

TRADE OR COMMERCE IN WILD ANIMALS, ANIMAL ARTICLES AND TROPHIES

The term trophy means the whole or any part of any captive animal or wild animal, other than vermin, which has been kept or preserved by any means, whether artificial or natural, and includes, rugs, skins, and specimens of such animals mounted in whole or in part through a process of taxidermy, and antler, horn, rhinoceros horn, feather, nail, tooth, musk, eggs, and nests. And uncured trophy means the whole or any part of any captive animal, other than vermin, which has not undergone a process of taxidermy, and includes a [freshly killed wild animal ambergris, musk and other animal products];

Sec. 39 of the Act, declares that every wild animal other than vermin, which is hunted or kept or bred in captivity or found dead or killed by mistake, shall be the property of the State Government. Likewise, animal articles, trophy or uncured trophy, meat derived from any wild animal, ivory imported to India, article made from such ivory, vehicle vessel weapon, trap or tool that has used for committing an offence and has been seized shall be the property of the state government. If any of the above is found in the sanctuary or a National Park declared by the Central Government then it shall be property of the Central Government.

PREVENTION AND DETECTION OF OFFENCES

Sec. 50 of this Act confers power of entry, search, arrest and detention on the Director or any other officer authorized by him or the chief wildlife warden or officer authorized by him or any Police officer not below the rank of Sub-inspector. Officer not below the rank of Assistant Director of Wildlife Preservation or Wildlife Warden shall have the powers to issue a search warren, to enforce the attendance of witnesses, to compel the discovery and production of documents and material objects and to receive and record evidence.

COGNIZANCE OF OFFENCE

No court shall take cognizance of any offence against the Wildlife Protection Act except on a complaint by: The Director of wildlife preservation or any other officer authorized in this behalf by the Central Government or; The Chief Wildlife Warden or any other officer authorized by the State Government; or, any person who has given notice of not less than 60 days, in the manner prescribed, of the alleged offence and of his intention to make a complaint to the Central Government or the State Government or the officer authorised as aforesaid.

PUNISHMENTS

Provided that where the offence committed is in relation to any animal specified inScheduled I or Part II of Schedule. II, or meat of any such animal, animal article, trophy, or uncurled trophy derived from such animal or where offence [relates to hunting in, or, altering the boundaries of] a sanctuary or a National Park, such offence shall be punishable with imprisonment for a term which shall not be less than [one year] but may extend to six years and also with fine which shall not be less than five thousand rupees. Provided further that in the case of a second or subsequent offence of the nature mentioned in this sub-section, the term or imprisonment may extend to six years and shall not be less than two years and the amount of fine shall not be less than ten thousand rupees. Any person who contravenes any provisions of Chapter VA, [Prohibition of Trade or Commerce in Trophies, Animal Articles, etc. derived from Certain Animals.] shall be punishable with imprisonment for a term which shall not be less then one year but which may extend to seven years and also with fine which shall not be less than five thousand rupees.

Any person who contravenes the provisions of Section 38J [tease, molest, injure or feed any animal or cause disturbance to the animals by noise or otherwise, or litter the grounds in a zoo] shall be punishable with imprisonment for a term which may extend to six months or with fine which may extend to two thousand rupees, or with both. Provided that in case of second or subsequent offence the term of imprisonment may extend to one year or the fine may extend to five thousand rupees As per section 52, whoever attempts to contravene, or abets the contravention of, any of the provisions of this Act or of any rule of order made hereunder shall be deemed to have contravened that provision or rule or order, as the case may be.

If any person, exercising powers under this Act, vexatiously and unnecessarily seizes the property of any other person on the pretence of seizing it for the reasons mentioned in sec. 50, he shall, on conviction, be punishable with imprisonment for a term which may extend to six months, or with fine which may extend to five hundred rupees, or with both.

FORFEITURE OF PROPERTY DERIVED FROM ILLEGAL HUNTING AND TRADE

A new chapter, Chapter VI-A, had been incorporated by the Wildlife (Protection) Amendment Act of 2002. According to this new chapter, if any person or associate of persons or trust acquires property from illegal hunting or trade of wildlife, it shall be forfeited to the State Government by the competent authority. Such property can be forfeited after taking all necessary steps (inquiry, investigation or survey in respect of any person, place, property, documents institution, etc.) and after tracing and identifying any such property.

During the investigation and proceeding of forfeit the property, if the competent authority finds that only a part of the acquired property is proved illegal, the authority shall make orders, giving an opportunity to the person affected, to pay a fine equal to the market value of such part of property in lieu of forfeiture.

CONCLUSIONS

The key environmental challenges that the country faces relate to the nexus of environmental degradation with poverty in its many dimensions, and economic growth. These challenges are intrinsically connected with the state of environmental resources, such as land, water, air, and their flora and fauna. The proximate drivers of environmental degradation are population growth, inappropriate technology and consumption choices, and poverty, leading to changes in relations between people and ecosystems, and development activities such as intensive agriculture, polluting industry, and unplanned urbanisation. The status of wildlife in a region is an accurate index of the state of ecological resources, and thus of the natural resource base of human well-being. This is because of the interdependent nature of ecological entities, “the web of life” in which wildlife is a vital link.

Moreover, several charismatic species of wildlife embody Incomparable Values, and at the same time, comprise a major resource base for sustainable development. Conservation of wildlife, accordingly, involves the protection of entire ecosystems.

We have to keep these perspectives in mind while going through the Wildlife (Protection) Act 1972. Since the wildlife is a vital link in the web of lives, it is our utmost duty to preserve and protect the richness of wildlife as it can be made available to generations. So, the endangered species of flora and fauna should be protected. The Wildlife (protection) Act, with timely amendments, facilitates the protection of wild life in India.

WILD LIFE (PROTECTION) AMENDMENT ACT 2013

The Wild Life (Protection) Amendment Bill, 2013 was introduced in the Rajya Sabha on August 5, 2013. The Bill has been referred to the Standing Committee on Environment and Forests. The Bill seeks to amend the Wild Life (Protection) Act, 1972. This Act provides for the protection and conservation of wild animals, birds and plants. It also covers the management of their habitats and regulation and control of trade or commerce linked to wild life.

According to the government, India is a party to the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES) and amendments to the Act are necessary for India to fulfil its obligations under the CITES. The key amendments made by the Bill are:

- The manufacture, sale, transport or use of animal traps except for educational and scientific purposes (with permission) is prohibited.
- Under the Act, destruction, exploitation or removal of any wildlife including forest produce from a sanctuary is not permitted, except with a permit. The amendment allows certain activities such as grazing or movement of livestock, bona fide use of drinking and household water by local communities, and hunting under a permit.
- Provisions to regulate international trade in endangered species of wild fauna and flora as per the CITES have been inserted. A schedule listing out flora and fauna for purposes of regulation of international trade under CITES has been added.
- The Tiger and Other Endangered Species Crime Control Bureau has been changed to the Wild life Crime Control Bureau.
- The term of punishment and fines for commission of offences under the Act have been increased.

- The Bill protects the hunting rights of Scheduled Tribes in the Andaman and Nicobar Islands.

This Act has VI Schedules where various species have been listed as per their conservation and protection status.

Schedule I: Species listed in this schedule have highest level of protection and conservation priority. This contains the "most threatened" animals and birds such as tigers and elephants. They are offered highest protection. It is again sub-divided into parts, as follows:

Part-I Mammals

Part- II Amphibians and Reptiles

II A Fishes

Part-III Birds

Part-IV Crustacean and Insects (Butterflies and Moths)

IV A Coelenterates

IV B Mollusks

IV C Echinodermata (Sea Cucumber)

Schedule II: Divided into Part I: It Contains mammals and reptiles whose trade or handling requires a licence. It includes bonnet macaques and chameleon (e.g. Rhesus macaque) and Part II: It contains only beetles. The list is given as importance as Schedule I.

Schedule III: This schedule contains mammals which cannot be hunted but dealing with animal articles requires licence. It has animals like nilgai and wild boar and many other animals.

Schedule IV: This schedule contains birds that cannot be hunted but dealing with bird articles and trophies requires licence. It includes rose-ringed parakeet as well.

Schedule V: contains vermin living in the wild. The list contains common crow, fruit bats, mice and rats, and they can be freely hunted. Common Crow, Fruit Bats, Mice and Rat are included in this schedule and as per Section 62 of Wildlife (Protection) Act, 1972 all these animals can be killed after declaring them Vermin through this act with proper permission from authorized person.

NON-INSECT PESTS OF AGRICULTURAL IMPORTANCE AND THEIR MANAGEMENT

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Agriculture has been facing the destructive activities of numerous non insect pests from time immemorial, leading to radical decrease in yields. Pests are constantly being introduced to new areas either naturally or accidentally, or, in some cases, organisms that are intentionally introduced become pests. There is a group of animals other than the insects, which cause the considerable yield losses to agricultural crops and commonly called as non insect pests. Non insect pests of agricultural importance include phytophagous mites, plant parasitic nematodes, molluscs, crabs, millipedes, birds, and mammals however, among them mites, snails and slugs are serious pests of plants often causing severe losses to economic crops quality wise and quantity wise in Indian agricultural system.

PHYTOPHAGOUS MITES

Insect pests have received due attention, whereas mites have remained neglected probably due to their microscopic size and obscure nature, even though they have the potentiality of causing extensive damage to agricultural crops. The mite problem in agriculture has gained further importance in recent year because many of plant mites earlier considered to be innocuous are becoming major pests. It may be due to indiscriminate and injudicious use of broad-spectrum pesticide which kills the natural enemies.

Ticks and mites comprise a large arthropod belonging to the order Acarina of the class Arachnida. Mites can be distinguished from their insect relatives by the two body regions (cephalothorax and abdomen in some orders, these two parts are fused), sucking mouth parts, lack of antennae and four pairs of legs (as adult). Mites are among the most diverse and successful of all the invertebrate groups. They have exploited diverse habitats and because of their small size and cryptic appearance, are difficult to detect. The body plan is comparatively different to that of other arthropods, divided into two parts, generally possesses eight legs and devoid of antennae and wings. The colour varies from species to species. Agricultural importances of mites as pests of horticultural and agricultural crops are being appreciated all over the world and have caused great concern to both farmers and agricultural scientists with regards to their management. Unlike many insects, mite damage to plants is often slow and in the initial stage damage symptoms are often confused with that of nutrient deficiencies. More than 40,000 acarine species are known from diverse habitat. Around 7,000 species of plant feeding mites are known worldwide which belong to five important families. In India, a total of 660 mite species are known, of which 169 are represented by phytophagous mites. It has been evaluated that losses in crops due to mite damage are as high as 3.5 to 10 % in wheat, 2 to 11 % in barley, 30 % in ber, 57 to 90 % in sorghum, 13 to 31% in brinjal, 23 to 27 % in okra, 27 to 39 % in chillies and 18 to 22 % in cucurbits. Sometimes total failure of crop as a result of mite infestation is also observed. Since last few years, the menace of mites on different crops is becoming serious in Rajasthan because of which farmers have to bear with heavy losses in productivity and production. However, many mites are beneficial to man as they prey on undesirable arthropods and phytophagous mite species.

LIFE CYCLE OF PHYTOPHAGOUS MITE

Normally mites have four stages in their life-cycle viz. egg, larva, nymph and adult. Females normally lay round, white, pink, red or light-yellow eggs mostly on the lower surface of the leaves. In general, each female lay 5 to 20 eggs per day. Young larva having six legs emerges out of the egg after an incubation period of 4-5 days. After about 2-3 days, the larva changes into eight legged two nymphal stages (spider mites and false spider mites) or three nymphal stages (many predatory mites) or no nymphal stage (many tarsonemid mites) and finally reach eight-legged adult stage. However, in eriophyidae, two pairs of legs are present throughout the developmental stages, including the adults. Usually life-cycle is longer in winters and shorter during summers. Females are normally larger than the males. The growths of different stages in the life cycle are dependent on the external temperature regimes.

DAMAGE OF PHYTOPHAGOUS MITE

Mites pierce the plant tissues with their piercing and sucking type of mouth parts and suck the cell sap. During this process, they damage leaf tissue, destroy chlorophyll resulting in change of photosynthesis and transpiration rate. The affected leaves start falling and the plant growth also stops at very initial stage. While feeding, some species inject toxins through saliva which cause various malformations and deformities (citrus, guava), gall formations (ber), blister (sugarcane), russeting (citrus) etc. Similarly, some mites also spread plant diseases, viz., mosaic in figs, sterility mosaic in pigeon pea, streak mosaic in wheat and mosaic in bean crops. Some mites spin a web of silken threads over leaves, flowers and fruits which affect photosynthesis adversely. Usually mite attack starts from border of the crop field and later spreads to the entire field.

MAJOR FACTORS FOR MITE OUT BREAK

1. Elimination of natural enemies as a result of indiscriminate and injudicious use of pesticides for general pest control.
2. Adoption of improved agricultural practices, intensive cultivations of crops, high yielding varieties and higher doses of nitrogenous fertilizers which provide congenial conditions for their growth and multiplication.
3. Use of organophosphours and synthetic pyrithroids causes development of resistance in mites and pest outbreak due to increased reproductive potentiality of mites.
4. Raising monoculture or single variety over large areas leads to extensive food supplies for mite pests.
5. Because of climate changes and its consequences in present context.

SPREAD OF MITE INFESTATION

Mite infestation spreads very rapidly from one field to another due to their efficient dispersal mechanism as:

1. Mites are blown away by wind and air flow due to temperature gradient.
2. Mites are often carried from one field to another by intervention of different organisms such as insects, birds and men himself.
3. Transportation of hosts in case of mites infesting plant materials.
4. Mite-dispersal from one field to another takes place through crawling.

ECONOMIC IMPORTANCE SPECIES OF PLANT FEEDING (PHYTOPHAGOUS) MITES IN AGRICULTURE

Mites causing economic damage to crops belong to spider mites (Family: Tetranychidae), false spider mites (Family: Tenuipalpidae), gall mites or bud mites or blister mites (Family: Eriophyidae) and yellow or broad mites (Family: Tarsonemidae). Among phytophagous mites, eriophyids are to a great extent host specific, however other are not. Some of the salient features of important groups are:

A. Spider mites (Tetranychidae)

Spider mites occur on most of the major food crops and ornamental plants in almost all environments, where they mainly cause potential economic damage. Spider mites are soft-bodied, medium-sized mites. They are often red, green, orange or yellow in color when alive, colony forming and normally inhabit the under surface of the leaves, however, *Eutetranychus orientalis* and *Oligonychus* prefer upper surface. Many species except *Bryobia* and *Petrobia* spin web like spiders hence named. The size varies from 0.5 to 0.6 mm. The important economic species of spider mites are:

1. Oriental Red Mite, *Eutetranychus orientalis* (Klein)

E. orientalis is native from Asian and African regions, mainly associated with citrus plant but also have a wide range of other crops. Mites commence feeding on the upper side of the leaf along the midrib and then spread to the lateral veins, causing the leaves to become chlorotic. Pale-yellow streaks develop along the midrib and veins. Little webbing is produced. In heavier infestations, the mites feed and oviposit over the whole upper surface of the leaf. Very heavy infestations on citrus cause leaf fall and die-back of branches which may result in defoliated trees. Lower populations in dry areas can produce the same effect.

2. Red spider mite or carmine spider mite, *Tetranychus cinnabarinus* (Boisduval)

Adults and nymphs feed primarily on the undersides of the leaves. The upper surface of the leaves becomes stippled with little dots that are the feeding punctures. The mites tend to feed in "pockets" often near the midrib and veins. Silk webbing produced by these mites is usually visible. The leaves eventually become bleached and discolored and may fall off.

3. Brown wheat mite, *Petrobia latens*

Brown wheat mite causes problems in wheat that is already stressed due to lack of moisture. The mite first pierces cells on and near the leaf surface with its stylets and then sucks the sap from the leaf. This results in a very fine whitish or silverish mottling or stippling of the leaf. Prolonged feeding brings increased mottling and stippling as chlorophyll is withdrawn and the leaf assumes an overall pale yellow to bronze colour. Eventually the damaged leaf turns brown and dies. *P. latens* is mainly a pest in dry weather so the damage it does is very similar to that caused by drought. Usually mite populations build up first in the driest areas of a wheat or barley field. These heavily infested areas become yellow or brown and look as if they are parched. The entire field may eventually become yellow or brown. Brown wheat mites feed during the day, and the best time to scout for them is in mid-afternoon. They do not produce webbing and will quickly drop to the soil when disturbed. They are very susceptible to hard, driving rains, but until then they can cause yield loss when present in large numbers.

B. False spider mites (Tenuipalpidae)

They look like spider mites but they do not spin web. The false spider mites are also known as flat mites because most species are dorso-ventrally flattened. These mites are pear shaped and mostly bright coloured. They are slow-moving and are usually found on the lower surface of the leaves near the midrib or veins. Some species feed on the bark while others live in flower heads, under leaf sheaths or in galls. Only a small number of species belong to a few genera have become pests of economic plants and they are most commonly found on tropical fruit crops and ornamental plants. The size varies from 0.30 to 0.35 mm. The important mite of this group is ber gall mite.

1. Ber gall mite, *Larvacarus transitans* (Ewing): This mite caused blisters/ galls on ber plants, *Ziziphus mauritiana* Lam. The twigs of bushy ber cultivars were found heavily infested by this mite. On the average, 20 to 80% of the bushes were infested. Distinctive characters of this mite are the presence of three pairs of legs in both nymphal and adult males and females. The galls rupture during monsoon. After emerging from the galls, the mites hide themselves in cracks and crevices of tree trunk, starting new infestations. The intensity of gall formation was higher on local than on improved cultivars. Twigs bearing galls bore less fruits than healthy twigs.

C. Gall mites (Eriophyidae)

Eriophyoid mites are tiny worm-like or fusiform mites and they form galls or live freely on various host-plants. Apart from leaves, they also live within buds. Many species form blister and most commonly form galls. The size varies from 0.20 to 0.25 mm. The important species of gall mites are *Eriophyes cernuus* who feed on ber, khejri and *Aceria granati* who feed on pomegranate.

D. Yellow or broad mite (Tarsonemidae)

Tarsonemid mites are tiny, glossy/yellow mites, fast moving, exhibit various feeding habits, some species feed on fungi, algae, plants and some of them can prey on parasitic insects. These mites feed on surface cells, more significant damage is observed in young tissues of the host plant. Symptoms are characterized by leaf discoloration with a silver aspect. The size varies from 0.25 to 0.30 mm. The important phytophagous mite of this family is yellow chilli mite, *Polyphagotarsonemus latus*.

INTEGRATED MANAGEMENT OF MITE PESTS

In present context, the most common way to manage mite pests is through the use of chemicals. Majority of the chemicals that are in use show broad spectrum activity and induce side effects which are quite undesirable in the interest of the environmental safely and to the population of beneficial insects and other organisms of economic value. A planned integrated and ecologically based approach should therefore be designed for the management of the mite pest problems.

A. Cultural control

1. Clean cultivation and maintenance of field sanitation through destruction of stubbles and removal of weeds.
2. Balanced use of fertilizers and pesticides.
3. Avoid monoculture and traditional farming.
4. Intercropping and mechanical manipulation of soil as per need.
5. Pruning especially in fruit plants to avoid excessive density at initial stage of plant.
6. Removal and destruction of infested plant parts on visibility.
7. Use of resistant varieties and improved short duration verities.

B. Biological control

(i) Predatory mites –

S. No.	**Predatory mites**	**Host mites**
1.	*Amblyseius alstoniae*	*Petrobia latens, Tetranychus neocaledonicus, T. ludeni, T. cinnabarinus* and *Eutetranychus orientalis*
2.	*Amblyseius pruni*	*Aceria granati* and *E. orientalis*
3.	*Chelatogenes ornatus*	*Larvacarus transitans*
4.	*Amblyseius ovalis*	*Polyphagotarsonemus latus*

(ii) The coccinellid beetles are predominately predator on *T. cinnabarinus, T. neocaledonicus, T. ludeni, T. urticae* and *P. latus*

C. Use of plant products

Neem seed kernel extract (5%), neem oil (2%), datura leaf extract (1%), Calotropis leaf extract (5%) and karanj seed extract (5%) have shown promise as acaricides.

D. Chemical control

1. Pesticides may be sprayed in appropriate dose, when it is very much essential.
2. Pesticidal application should give good coverage to reach concealed niches like axillary buds, gall etc. to avoid infestation through post spray surviving population for better control the surrounding plants, weeds, etc. should also be sprayed as these serve as alternate hosts.
3. A selective pesticide is better than a broad spectrum one as the later often kills the natural enemies.
4. Pesticides like dicofol 18.5 EC (0.05 %), ethion 50 EC (0.05%), sulphur 80 WP (0.25%), oxydemeton methyl 25 EC (125 g a.i./h), thiamethoxam 25 WG (0.02%), profenophos 50 EC (0.05%) and propargite 57 EC (285g a.i./h) have

been found to be very effective against mites and proved least harmful to natural enemies.

SNAILS AND SLUGS AS AGRICULTURAL PESTS

Snails and slugs are the animals without backbones, having asymmetrical, unsegmented and spirally coiled body, belongs to class gastropoda. Snails have a well-developed shell while, slugs have only a rudimentary shell often enclosed in a visceral hump. These creatures are hermaphrodites in nature but there is reciprocal exchange of spermatozoa as they mature before development of eggs. Snails and slugs are among the most destructive pests found in gardens and landscapes. During day time they hide in moist places or under debris and feed mainly at night when the temperature drops and humidity rises. Snails secrete light yellow slime and slugs secrete colourless slime which becomes silvery after drying. In India, around 1500 species of terrestrial snails occurs but the numbers of species of slugs are limited however, out of which nine species of snails and 12 species of slugs have been reported as the pest of ornamental plants, vegetables, fruits and field crops.

The common snail, *Helix* spp., is found in Himachal Pradesh, Uttar Pradesh, Andhra Pradesh, Bihar, Maharastra and Odisha. The giant African snail, *Achatina fulica* Ferusac, has been also reported to be serious pest of fruits, vegetables and ornamental plants in the coastal areas of Odisha, West Bengal, Assam, Tamil Nadu and Kerala. The common garden snail, *Laevicaulis alte* Ferusac, has been observed feeding on a number of ornamental plants including balsam, portulaca, pot-marigold, verbena, dahlia, cosmos, narcissus and lily in Punjab and Himachal Pradesh. The seedlings of several economically important plants are also attacked by black slug, *Filica ulisalte* Ferusac. Slug, Limax spp is also infesting different crops in all over the India.

LIFE-CYCLE OF SOME MAJOR SPECIES

Snails and slugs are hermaphrodites in nature and both members of a mating couple can lay eggs. Mating usually takes place from mid-autumn to mid-winter when favourable climatic conditions are available. Two to four weeks after mating, eggs are laid into moist soil. However, eggs cannot survive a hot, dry summer or lie dormant in the soil. After laying, eggs hatch in two to four weeks, but young slugs and snails usually become sexually mature after one year.

1. Giant African snail (*Lissachatina fulica*, previously known as *Achatina fulica*): The snail attacks more than 500 types of plants, but it prefers breadfruit, cassava, cocoa, papaya, peanut, rubber and most species of legumes and cucurbits. Cuttings and seedlings are especially vulnerable. Damage is greatest when outbreaks first occur in a new area. The snail has male and female sex organs (hermaphrodite), but reproduction requires cross-fertilization. Eggs are first laid when females are about 6 months' old. The eggs are cream, about 5 mm diameter, laid below the soil surface or on the sides of logs, in batches of 200 to 300. The eggs hatch within 1 to 2 weeks. One snail can lay up to 1000 eggs each year and snails live for up to 5 years.

2. Garden slug (*Laivicaulis alte*): It lays eggs in groups of 6 to 45 in moist soil. Maximum egg laying is seen in the month of September. Eggs are oval, whitish or creamish in colour and transparent, strung along a thread. Incubation period ranges from 9-18 days with an average of about 13 days. Adults mature within a period of 240-323 days with an average of 271 days and measure 55 mm in breath and 50 mm in length. They are found in soil under debris and survive during unfavourable conditions like food scarcity and low moisture during summer months. They remain active throughout the year but their severity is noticed in cool and damp situations.

3. Brown slug (*Filicaulis alte*): It lays dirty creamish white spongy eggs in masses (74-80 eggs/mass) on damp soil in polythene bags containing nursery plants. Newly hatched juveniles resembling adults in colour and appearance tend to remain close to the hatching spot and start feeding immediately. They become mature and start egg laying at the age of about 8-9 months and lay eggs twice a year. The adult is about 8.0-8.5 cm in length, 1.5-2.0 cm in breath and 7-8 gin weight. Average life span is 390 days.

4. Some other species: The brown garden snail, *Cornu aspersum* (formerly *Helix aspersa*); white garden snail, *Theba pisana*; gray garden slug, *Deroceras reticulatum*; banded slug, *Lehmannia poirieri*; the three-band garden slug, *L. Valentiana*; the tawny slug, *Limacus flavus* and the greenhouse slug, *Milax gagates* are causing damage to various crops in different parts of the globe.

NATURE OF DAMAGE

During rainy season snails come out of their hiding places and destroy many vegetables, ornamentals, plantation and fruit crops. During day time they hide below fallen leaves and stones; also climb on papaya, banana and many other plants and remain clinged to the lower and protected surface of leaves. Slugs are nocturnal however active feeding can also be seen in day especially during morning hours when weather is showering or dumpy. They cut and devour tender plant parts like flowers, leaves etc., normally from margins. During rainy season their nuisance value is observed especially in the lawns during morning walks. Snails and slugs feed on a variety of living plants and on decaying plant matter. They create irregular holes with smooth edges on leaves and flowers by scraping with their rasp-like tongues. Small succulent plant parts are easily clipped by snail and slug feeding. Because they prefer succulent foliage or flowers, snails and slugs are primarily pests of seedlings and herbaceous plants. They are also serious pests of turf grass seedlings and ripening fruits that are close to the ground, such as strawberries and tomatoes. Snails and slugs will also feed on the young plant bark and foliage and fruit of some trees. Citrus are especially susceptible to damage.

MANAGEMENT OF SNAILS AND SLUGS

1. Cultural methods: Cultural control is cheapest and important for early management of the pests. The following cultural practices should be done:

- Several types of barriers (erecting vertical copper screens, banding tree trunks, wrap the copper foil around the trunk, dry diatomaceous earth) will also keep away snails and slugs from planting beds
- Hand picking of snails and slugs should be done regularly, preferably by mobilising the community, schools in particular, then bury them or feed them to pigs after boiling for an hour.
- Collect the snails and slugs and put in to a bucket containing common salt.
- Grow vegetable gardens or susceptible plants as possible as far away from snail and slug hiding areas. Reducing hiding places allows fewer snails and slugs to survive, these survivors congregate in the remaining shelters, where they can easily locate and managed.
- Switching from sprinkler irrigation to drip irrigation and timing of irrigation (near sunrise) also reduce humidity and moist surfaces, making the habitat less favourable for these pests.
- Soil solarisation should be done before raising a nursery or planting.
- Choose plants that are not attractive to snails and slugs for areas where they are in high population.
- Different traps like inverted melon rinds, wooden traps and beer-baited traps are effective practices for the management of snails and slugs in garden and landscape.
- Impregnate sunny bag with 15% salt solution and place the gunny bags at random in the field (approximate: 10/ acre)
- Conduct awareness campaigns among communities to aware them about –
    - Snails and slugs should not be kept as pets
    - They are a threat to human health
    - The collaborative community action is needed to control them.

2. Natural enemies: Snails and slugs have many natural enemies, including ground beetles, rats, pathogens, snakes, toads, turtles, and both domestic and wild birds. Most are rarely effective enough to provide satisfactory control in the garden.

- Predatory snails, *Euglandina rosea* and *Gonaxis quadrilateralis*, and flatworms, *Platydemus manokwari* have been introduced to control the snails, but the effects have been a disaster for local snail populations. Environmental impact studies are essential before the introduction of these predators because of their non-specific nature.
- Domesticated fowl (such as ducks, geese, or chickens) are effective snail predators in nature.

3. Chemical control: Several types of snail and slug bait products or molluscicides are available in the market. These baits are more effective when combine with a cultural program in a large area.

- Iron phosphate baits (trade names - Sluggo and Slug Magic) are safer for use around children, domestic animals, birds, fish, and other wildlife in gardens.
- Products that contain ferric sodium EDTA work in a similar manner to iron phosphate but are somewhat faster, killing snails in three days instead of seven.
- Metaldehyde baits (2.5 % DP) are easily available and also effective for the management of the snails and slugs but, poisonous to dogs and cats, and the pelleted form can be attractive to dogs. Do not use metaldehyde snail baits where children and pets could encounter them. Avoid getting metaldehyde bait on plants, especially vegetables.
- Prepare following poison baits to kill the slugs and snails –
    - Dicholorvos bait (Wheat flour - 1 kg + Jaggery - 0.2 kg + Dichlorvos 76 EC - 250 ml)
    - Methomyl bait (Rice bran - 1 kg + Jaggery - 0.2 kg + Methomyl 40 SP - 100g)

      Make jaggery syrup in low heat and mix wheat flour/rice bran along with the poison. Make small balls and keep it in 10 places in the field with attractant. Wear proper protective gloves while preparing the baits. Keep away the poultry and pet animals from the baited field.

- Placement of baits - Baiting is less effective during very hot, very dry, or cold times of the year because snails and slugs are less active during these periods. Sprinkle the baits on the soil areas where snails and slugs regularly visit, near but not on plants that are attractive to the pests or near pest hiding places such as irrigation boxes. Applying the bait in the late afternoon or evening when snails and slugs are active will take advantage of the night time feeding habits of these pests and will improve the success of baiting.

BIO-ECOLOGY OF BLUE BULL OR NILGAI AND ITS MANAGEMENT IN AGRICULTURE LANDSCAPE

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INTRODUCTION

Blue bull or Nilgai (*Boselaphus tragocamelus* Pallas, 1766) is the largest antelope in Asia, about the size of horse. An adult male stands upto 140 cm at shoulder height (Walker 1968, Prater 1971). Average body weight could be around 250-270 kg (Prater, 1971). The male of this species has which are short (15-20 cm), stout, conical and smooth in nature. Nilgai calves and cows (female) are light brown in colour. The light brown colour of male calves begins darker from tenth month and they develop black legs and brownish grey shoulders by the end of two-year age. Adult nilgal bulls (male) are steel-grey or blue-grey in colour with black legs, which is developed by the fourth year (Sheffield et al., 1983). Both the sexes have dark and white markings on their heads, ears, under-parts and tail, and prominent white vibrissa spots on the head. At the midpoint on the ventral side of the neck is a tuff of hair, more pronounced in bulls than in cows (Sheffield et al., 1983). Only male nilgai have horns which are short (15-20 cm), stout, conical and smooth in nature. Nilgai calves and cows are light brown in colour. The light brown colour of male calves begins to darken by the tenth month and they develop black legs and brownish grey shoulders by 18 months. Adult nilgai bulls are steel-grey or blue grey in colour with black legs, which is developed by the fourth year (Sheffield et al. 1983). All individuals have dark and white markings on their heads, ears, under-parts, fetlocks, and tail. At the midpoint on the ventral side of the neck is a tuft of hair, more pronounced in bulls than in cows (Sheffield et al. 1983).

CLASSIFICATION

Order	Artiodactyla
Family	Bovidae
Sub-family	Bovinae
Genus	Boselaphus
Species	*B. tragocamelus*
Common name	Nilgai/Bluebull/Rojara

DISTRIBUTION

Nilgail are an endemic species of peninsular India. The present distribution of nilgai ranges from Himalayan foothills, southwards through central India, down to southern part of Andhra Pradesh and upto semi-arid part in west and absent in the north-east India, and the southern most part of the peninsular region. It has been also reported from Pakistan, especially near the Indian border (Mirza and Khan, 1975, Roberts, 1977) and in Nepal (Dinerstein, 1979). The introduced population also successfully breeds in U.S.A., Mexico and South Africa (Lever, 1985).

Nilgai mainly occurs around human habitation and crop fields. Generally found in variety of habitats, ranges from plains, undulating hills, scattered trees to the cultivated plains, whereas avoids dense forest and steep hilly terrain (Blanford, 1888). In Rajasthan, its distribution is wide and found almost all kind of habitats. Its population is high in outside of protected areas as compared to national parks and sanctuaries. They can be easily observed in the double cropping areas. In many parts of India, they enjoy complete protection, being regarded as a relative of cow, close to Lord Shiva and hence considered sacred by various communities. Northern states, especially Haryana, Madhya Pradesh, Rajasthan and Uttar Pradesh account for a large population (about 60%) of the total nilgai population in the country (Sankar et al., 2004).

GENERAL ECOLOGY

Nilgai are social animals, and lives in small groups ranging from one to ten, whereas their group size varies seasonally. In Sariska, seasonal group size varied greatly, from two to 43 individuals, with a mean group size of 4 individuals per group (Sankar, 1994). There are total three distinct kind of social grouping was recorded (Schaller, 1967), (i) one or two cows with young calves, (ii) three to six adult and yearling cows with calves, and (iii) all male groups of different age classes, varying in number from two to 18. A group of all male class was recorded with a maximum 27 individuals from Khimsar region (Distt. Nagaur, Rajasthan) during a survey in winter season (S. Dookia Per. Observ.). Their social structure and number of family members changes constantly during breeding and non-breeding season.

The sex ratio in Nilgai population is always females biased with an average of 0.4 to .89 male: 1 female in wild, whereas in captivity it was ironically same as male (Jarvis, 1968). Sankar (1994) reported 0.4 male: 1 female in Sariska forest. The female: calf ratio for free ranging nilgai is 1: 0.23 to 0.48. The higher number of young in nilgai, as compared to sympatric ungulates can be attributed to twinning and strong defence of calves by cows making them less vulnerable to predation (Kyle, 1990, Sankar, 1994).

The rutting season varies from place to place, Schaller and Spillett (1966) reported during the rainy season (June to October) and breeding activity occurred from October to February, with a peak in November and December. Sankar (1994) also reported same season of breeding and calving from Sariska.

FOOD HABITS

Nilgai is a browsers or mixed feeders. It can thrive upon variable proportions of grass, herbs, and browse, subject only to a minimum requirement of protein, which must not be below 8 per cent of their intake. A study of ungulate food habits in Nepal (Dinerstein 1979) indicated that sambar and nilgai feed on the same browse species. Apart from this, there is little information available on the dietary overlap between nilgai and other wild ungulates. According to Rodgers (1988), the large size of nilgai means they can exist on much poorer quality food items, making them coarser browsers. They are also fond of raiding crops and are regarded considered as pests in agriculture fields. Their ability to reach up to a great height helps in reaching and gaining accessibility to forage on lower canopy of trees. At many times, it was observed that nilgai standing on hind legs and feeding on Zizyphus mauritiana, Tecomela undulata and Prosopis cineraria branches, leaves and fruits (S. Dookia pers. observ.). It is very generalist in diet and can feed on variety of plants available round the year.

WATER DEPENDENCE

The availability of surface water influenced the distribution and movements of many animals including nilgai. According to Prater (1971) nilgai can go for long periods without water, and even during the hot weather, nilgai do not need to drink water regularly. Nilgai are reported to be water independent even in desert areas (Bohra et al., 1992). The water availability in western Rajasthan, after systematic planning and canal irrigation, increased many folds. This provided ample opportunity for nilgai to explore newer areas and its population increased catastrophically in irrigated areas. As per records available with Desert National Park authorities, no nilgai was reported till 2004-5. Invasion of nilgai started through Indira Gandhi Canal Project side (from Bikaner towards Jaisalmer) and now it is common in many parts of Jaisalmer district, can be seen regularly in Desert National Park too.

BREEDING BIOLOGY

During the breeding season, the bulls move about in search of breeding cows (female nilgai is know as cow and male as bull), and upon finding one, defend the area around her from intrusions by other males - a system described as 'roving territoriality' (Sheffield et al. 1983). Mature bulls maintain an area of dominance around themselves, whether or not cows are present. Breeding bulls respond to intrusions into these areas from other bulls by displays, threats, and chases, which either results in the intruding bulls leaving, or remaining in the area in a subordinate status. Courtship in nilgai is simple and involves a neck-stretched-forward, tail erect display by the male, showing the conspicuous white ventral side, and following the female in oestrus during a slow, sedate mating march.

FIGHTING

Walther (1974) described two types of fighting in nilgai bulls: (i) the combatants stand or kneel, and butt each other on the forehead with their horns, (ii) a neck-fight, in which both animals either stand or kneel, and push their necks against each other. Nilgai are the only bovids that exhibit neck-fighting between horned bulls. However, hornless cows of several bovids (including nilgai) neck-fight, which Walther (1974) considered phylogenetically very old, and suggested that it was also part of the behavioural repertoire of hornless ancestors of the modern horned ungulates. The persistence of this behaviour in nilgai bulls may relate to their relatively primitive horn structure. Since these horns are ineffective binding instruments, the common and more highly evolved head-to-head shoving with crossed horns (as observed in gazelle and kudu), has not developed in nilgai

CALF BEHAVIOUR

As seen in several species of ungulates, nilgai calves remain hidden for a while after birth, a habit called `lying out'. Twin nilgai calves born in captivity spent their first 10 days sleeping inside a shed, and rising only to nurse at two-hour intervals (Lacey 1969).

DUNG PILES

Nilgai is having a characteristic habit of defecating repeatedly at the same spot, resulting in the formation of large faecal heap or lavatory site (Brander, 1923, Schaller, 1967). The social significance of this particular behaviour is yet to known. Schaller (1967) suggested that these piles might function as territorial markers, since this behaviour is characteristic of several species of African antelopes (Leuthold, 1977).

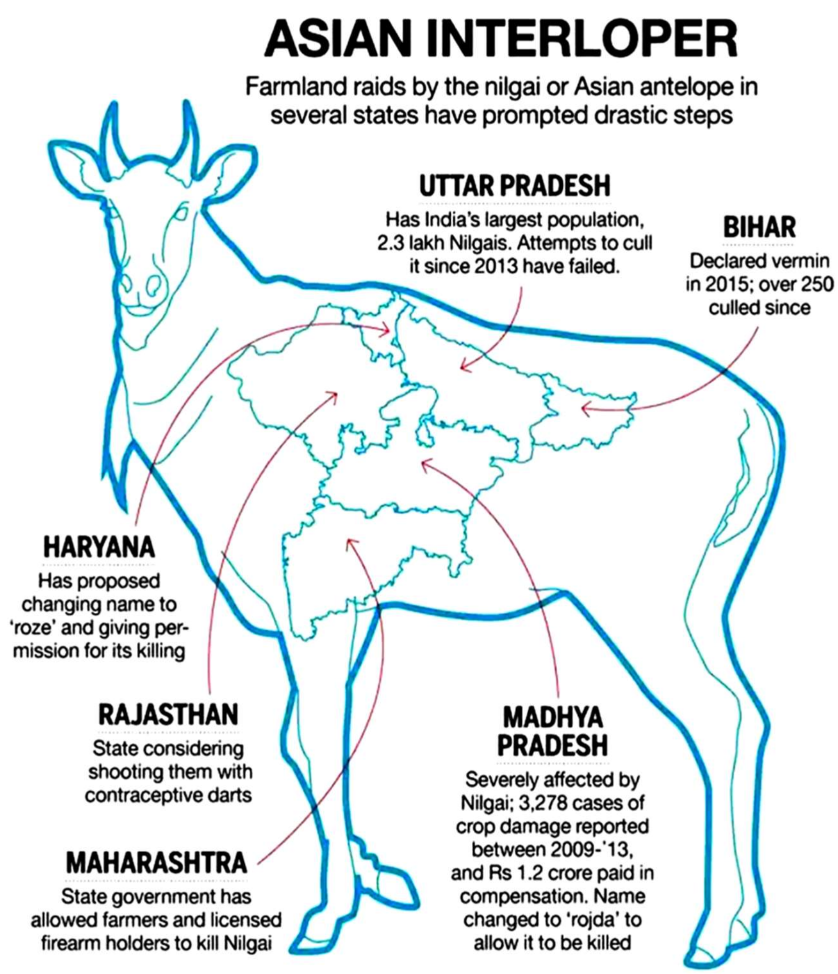
THREATS TO NILGAI

In Rajasthan nilgai found largely outside the protected areas, where no natural predator found, whereas very little information is available on mortality other then natural predation. Once reported with the symptoms of foot-and-mouth disease from Sariska (Sankar, 1994).

IN CONFLICT AS CROP PEST

Because of conversion of wastelands, grassy and open plains to agricultural lands coupled with religious sentiments attached to it because of its local vernacular name, nilgai (meaning blue cow – cow being holy and sacred for Hindus), the animal has grown in numbers outside protected areas rapidly. This expansion of agriculture, and rapid growth in its population, has been cause of destruction of crops by it in most of the states of the country. Out of the 16 states where it is found, the states of Bihar, U.P., Rajasthan, Gujarat, Haryana, Punjab, Madhya Pradesh and Uttarakhand are the worst affected

Being large in body size, without natural predator in its distributional range, gives it an advantage to roam freely in the vast landscape in large herds. It prefers open grassland and savannas, is a significant agricultural pest in India and is endemic to the Indian subcontinent (Leslie 2008). Locally called rojara, it is infamous for destroying crops, Blue Bull menace is sometimes a topic of discussion in the corridors of power, especially in state assemblies. Lack of predators of this antelope couple with its high growth rate due to multiple births (generally one fawn but twins, triplets and quadruplets are also observed in western Rajasthan) this species has increased considerably and become locally overabundant in many states viz. Gujarat, Uttar Pradesh,



Haryana, Punjab, Rajasthan, Madhya Pradesh and Delhi, thereby causing serious problems which include damage to crops leading to huge economic losses to the farmers. It causes considerable annual damage to agriculture, property, human health and safety, and natural resources. Agro-ecosystems have provided many new opportunities for vertebrates to exploit, resulting in their becoming serious "pests" with humans taking various steps to protect their agricultural resources. This conflict has intensified as the human population has increased, efforts to get more production out of traditional croplands have intensified, and marginal lands have been placed into crop production. Additionally, as the human population has increased, people have moved into lands occupied by wildlife, resulting in more human-wildlife encounters and conflicts.

THE NEED OF AN HOUR

In India, after the introduction of the Wildlife Protection Act (1972) and through associated management actions, the populations of many wildlife species have increased considerably, and a few of them have decidedly become locally overabundant. Due to disparate and often incompatible land use practices, these species have become ecological dislocates. Those that have been successful in adjusting to the man-altered habitats have thrived, and in many places such species have become serious pests of agricultural crops and are competing for resource utilization with domestic stock (Chauhan, 2011; Caughley, 1981; Howard and Dutta 1982).

In Rajastahn, locals facing serious problem from overabundant population of Nilgai (Boselaphus tragocamelus). Whereas on the other hand treated as sacred animal in various societies, and also absence of any natural predator favours in population growth. Nilgai, an antelope, is afforded holy and sacred rites by Hindus, and has rapidly grown in numbers outside protected areas.

Crop-raiding by locally overabundant populations of nilgai antelopes and rhesus monkeys has been widely reported in many parts of the country (Chauhan, 2011). The problem of crop raiding by nilgai antelope is wide across entire northern Indian states namely, Rajasthan, Haryana, Uttar Pradesh, Punjab, Gujarat, Madhya Pradesh and Delhi. The Nilgai conflict is very high in neighbouring districts of south-west Haryana, Uttar Pradesh and Madhya Pradesh.

This problem animal increased considerably due to prolonged breeding activity and a high rate of multiple births and lack of potential predators. They have become locally overabundant in these states, thereby causing serious problems which include damage to crops, economic losses and increased incidence of road mishaps due to vehicular collisions. Nilgai caused extensive damage to most agricultural crops, cash crops, fruit orchards and floriculture. Large number of options for damage control and managing nilgai populations are available but each of them has their advantages and limitations. Interestingly both these animals cannot be killed due to religious reverence and high level of public outcry.

MANAGEMENT IN AGRICULTURE LANDSCAPE

The overall population has been reduced in the overall range of nilagi, but the existing populations seem to be doing well. This is largely because of they are a protected species under the law, and more importantly the protection they acquire from considered sacred due to their resemblance to domestic cow. The constantly degradation of the natural forests, absence of large predator and the increase agricultural activities, has offered favourable habitat conditions. Invariably, this situation forced nilgai to become serious crop pests as crop raider and a major issue of human-wildlife conflict problem. One of the possible solutions is include a selective culling programme linked to licensed hunting permit under Section 62 of the Wildlife Protection Act, 1972 (WPA), to allow large-scale culling of wild animals (as recently used by State of Bihar). So far, only section 11 (b) of WPA, under which the state chief wildlife warden can permit hunting of wild animals, has been widely used by states to contain wild animals. Despite of the severity of the problem, very few come up to get license for culling.

Solving vertebrate crop pest problems requires a careful consideration of (1) the biology and population dynamics of the pest species; (2) the ecology of the species within its physical and biotic environment; and (3) an understanding of the relationships of the pest species to the activities of humans, including land uses, management practices, and other human activities (Conover, 2002). In India, problems associated with locally overabundant wildlife species have emerged as important management issues for reason of some species losing their natural habitat and adapting themselves to the man-altered situation. Understanding animal damage problems and their control is the prerequisite of resource management in most man-altered habitats to which wildlife species adapt successfully (Howthorne, 1971).

Possible mitigation strategies to reduce crop damage include use of fear-provoking stimuli, chemical repellents, fencing agricultural areas, capture and translocation, sustained harvesting, and reproductive management of nilgai populations. These management options are discussed herewith:

(i) Fear Provoking Stimuli: Fear-provoking stimuli are on-site devices by which animal's fear can be generated. These are visual (e.g. scarecrow, predator models, powerful lights) auditory (e.g. firecrackers, noise devices, siren, explodes, distress calls) and olfactory (e.g. predator odours). Most of the fear-provoking stimuli are effective for few days only as animals get quickly habituate to them. These stimuli have limited and have short term applicability. To get better effectiveness of the used stimuli, it should be altered frequently so that animal does not get habituated. Generally wild animals have a fear of loud sound. This can be used as a sudden sound burst, like fire cracker or programmed loudspeaker sound on the boundary of agriculture fields. If the same is repeated frequently and with a fixed interval in playing of such sound can lead towards learning by nilgai and it can be futile exercise in long run. Keeping this in mind, it can be used intermittently.

(ii) Chemical Repellents: All animals have likes and dislikes smell of certain chemicals. Repellents used in control of crop depredation by herbivore species are generally plant based or safe synthetic chemicals. When sprayed on the target crops it gives odd test through olfactory cues to animal for avoidance. One such chemical is known as Phorate. It is also known as Thimate and gives unpleasant smell for many days, from spraying sites. It is an organophosphate and used as insecticide and have toxicity to human too, so use of this chemical with caution. It has been reported by them that repellent effectiveness is influenced by its concentration, test duration, field size, plant palatability, availability of alternate forage, season of use and weather. Repellent use in India has limitations due to wet climate. However, it may be effective to protect high value crops during critical periods of its life cycle.

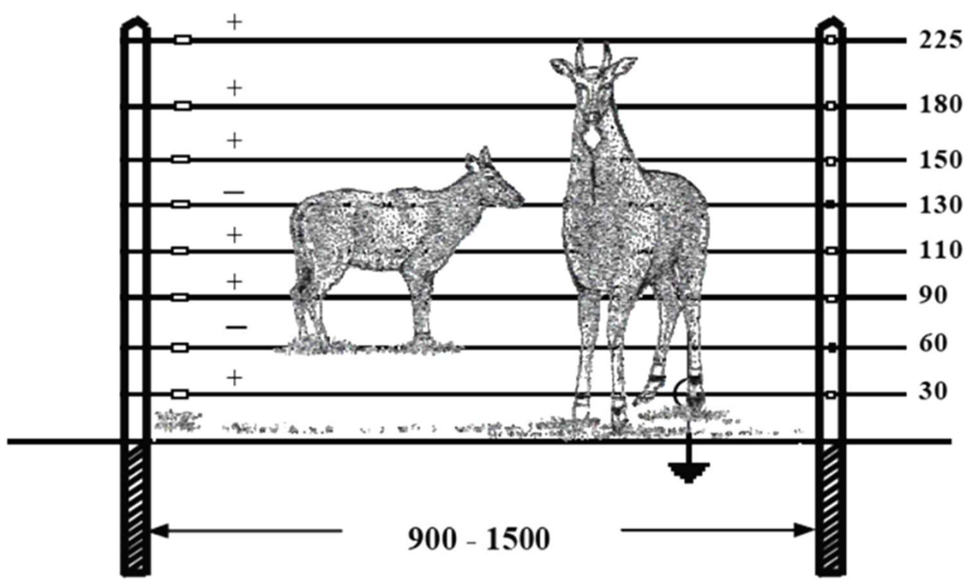
(iii) Fencing Agricultural Fields: Fencing is one of the best and non-lethal ways to keep away all unwanted animals. Since nilgai is known for jumping and crossing fences easily, height of fence should be minimum 6-7 ft. There are various ways of fencing, traditional fence, barbed wire fence, chain-link fence, green fence, etc.

a. ***Traditional fence:*** This is the most commonly used fence, where an earthen mound or 5-6 ft high and is covered with dead thorny bushes.

b. Barbed wire fence: Multiple barb wire can be used to fence the agriculture field. The distance between the wires can be reduced to make it ***more effective.***

c. ***Chain-link fence:*** This is another wire fence where wire mesh of different sizes comes in market, and as per the requirement, it can be erected around the field. There is no barb in the wire, hence, humane way of keeping nilgai away from the field.

d. ***Power Pulsating fence:*** Keeping away ungulates through fences or netting is one of the most effective and widely used methods. However, for containing blue bulls, high fences with several strands (7-8) would be required. It is usually expensive and therefore viable only in case of high economic value crops. Another important aspect in exercising this option is regular maintenance of fence to ensure its effectiveness. We recommend a 8 strand power fencing with wires on the height of 30, 60, 90, 110, 130, 150, 180 and 225 cms from the ground level (see figure below). In drier areas, two strands may be earthed. The cost of Blue bull proof power fence will depend on type of posts (wooden/iron) and accessories (brand) used for its construction. Average cost for a 8 strand power fence would be around Rs. 2.5 lakhs per km. Cost per km would be lower as the length is increased.



e Green fence: This is one of the best ways to keep unwanted animals away from the crop fields as well as humane approach for controlling crop pest. There are various hardy and fast-growing plants with long thorns and spines. For growing these plants, earthen mound is required. Sowing the seeds or planting these plants during monsoon season can allow them to grow faster. Within 2 years, the fence of these plants can make a good green fence, which is even not allowing bird to cross. If nilgai attempt to cross, the thorns and spines will lead to severe pain and in future the same animal will not attempt to cross.

(iv) Capture and Translocation: As name suggests, all the problem animals required to be captured and translocated. Wildlife translocation is another option. This option, though useful for quick mitigation has its own limitation.

One of the limitations is that the translocated animals may adversely impact other wildlife with new pathogen at new sites. Screening for disease is recommended before considering any translocation for restocking a depleted habitat. This requires a large fund, details of number of animals, technical expertise and permission from forest department, as nilgai is a wild animal and listed in Schedule III of Wildlife (Protection) Act, 1972. This work is not possible without support from concern authorities and scientific expertise. Large numbers of methods are available for physically restraining the deer and antelope species. These are: drop nets, drive nets, net gun, rocket nets and specially designed corrals, Peterson et. al.6. Adult Blue bull being large and strong will be difficult to handle in drop nets, drive nets, net guns and rocket net. The only suitable option available therefore is specially designed corrals to be constructed in open areas and allow blue bull to enter by providing lure food. Once confined, they can be taken out in boxes placed at mouth of the narrow tapering. Relocations of problematic animal, for the time being, seem the safest solution, but these problem animals start creating problem in the newer areas.

(v) Chemical Capture of Nilgai or Bluebull: The Blue bull are the biggest Asian antelope. They are strong and fast moving. Chemical capture of these animals is challenging and require skillful team and equipment. Widely used chemical immobilization and capture drugs for Blue bull include Etorphine hydrochloride, Xylazine hydrochloride in combination with Ketamine, and Meditomidine hydrochloride.

(vi) Fertility control: Fertility control is a method employed to keep wildlife population under check. This is generally done by mechanical and surgical intervention, endocrine disruption or immunocontraception. Each of these methods has advantages and disadvantages in managing wildlife population. Current efforts to control free ranging deer (white tailed deer, mule deer, elk deer and fallow deer) rely on use of immuocontraception, especially PZP (Porcine Zona Pellucida).

SCIENTIFIC MANAGEMENT OPTIONS FOR NILGAI PROBLEM IN FOR THE STATE OF RAJASTHAN

Owing to religious sentiments of the society, ill informed animal activist groups and hyperactive civil societies and complicated procedure associated to be followed upon, the authorized officers under the section 11 (2) (b) of the Wildlife (Protection) Act, 1972 remained reluctant in passing such orders of elimination of problematic nilgai. As the socio-economic conditions are a bit different in Rajasthan as compared to Gujarat, the Gujarat model can be tried in Rajasthan before switching to declaring blue bull as vermin under section 62 of the Act. Success chances of implementing the Gujarat model in Rajasthan with respect to authorization of sarpanches under section 11 (2) (b) of the act cannot be ruled out and depend on how we simplify the associated post elimination procedure of the problematic animals. In addition, awareness and sensitization programmes for the villagers and public sarpanches may play a major role in dealing with the problem. As long as there is balance between the tolerance to economic loss and religious sentiments, the farmer will be reluctant to kill the so called gai unless until if the balance is skewed more towards economic loss. In that case he may opt for eliminating the problem animals.

Declaring the species as “vermin” and to be brought in Schedule V of the under section 62 of the Act. Section 62 of Wildlife (Protection) Act empowers the central government to declare by notification wild animals other than Schedule I and part II of Schedule II to be vermin for specified area and period. It should be viewed as short term strategy and due care has to be taken by the decision makers and wildlife managers for using this option in a particular area for a particular period of time. For the same proper monitoring of the population of the target species has to be done by independent agency to know the status and demographic parameters. For the purpose, the status survey of the species has to be conducted using the help of scientific institutes so that the extent and magnitude of the problem can be quantified for decision making. The prevalent population estimation based on annual water hole count is unscientific, biased and always lead to unrealistic figures.

Government of Rajasthan has already exercised the legal option of allowing elimination of problem animals from agriculture landscape (i.e. areas outside notified forests), however even after these orders have been in force for many years now the problem of crop depredation by Blue bull has not been contained. Government of Rajasthan in its different orders P.11 (27) Forest/91 dated 3.3.94, P.11 (27) Forest/91 dated 19.1.96, P.11 (27) Forest/91 dated and 30.4.1997 authorized officers up to the rank of Range Officers for giving permission for the killing of blue bull under section 11 (1) (b) of Wildlife (Protection) Act, 1972. Subsequently vide its order F.11(27) Forest/91 dated 31.8.2000 Rajasthan government authorized Collector, Superintendent of Police, Sub-divisional officers, deputy superintendent of Police, assistant conservator of forests, Tehsildar, Naib Tehsildar and thana in-charges in all of Rajasthan for the purpose. So far none of the authorized officer has given permission for the purpose.

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INTEGRATED PEST MANAGEMENT FOR LOW RAINFALL AREAS

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The productivity of crops in dryland areas faces enormous challenges from both biotic and abiotic stresses. Among the biotic stresses, the infestation of insect pests is one of the major causes for yield loss in crops and horticultural plants. However, not all insects present in crops or orchards are pests, only a few species are damaging and inflict losses. Insects and humans have coexisted on this earth and have developed complex relationships. Insects like pollinators, predators and parasites are crucial to biodiversity of any ecosystem and have important roles to play in its functioning. Many of the ecosystem services provided by insects such as nutrient cycling, pest regulation and pollination – directly contribute to agricultural production (Losey and Vaughan, 2006, Lars, 2009, www.scientificamerican). Those insects which compete with human beings for food, cause injury or spread disease in humans, animals, crops etc are considered to be pests. The insects which cause serious damage or injury are termed major pests, while the ones which inflict only a small degree of damage are called minor pests. Some scientists claim that less than 0.5 percentage of the total number of the known insect species are pests, and only a few of these can be a serious menace to people. Many insect pests cause considerable damage to various crops. Dhaliwal estimated crop losses due to insect pests in India to be to the tune 17.5 per cent and monetary annual loss of about Rs. 8, 63, 884 million (Dhaliwal et al. 2010).

Pests in arid regions can be either polyphagous, which infest many crops or monophagous which are specific for a particular crop. The pests can be categorized as per the crop or according to the type of injury they cause. According to the type of damage insect pests can be defoliators, which devour leaves; sucking pests, which feed on the sap of plants from leaves, flowers seeds or pods; the borers, which feed on stem, pod or fruit by entering inside the plant tissue or the root feeders. The measures for managing these pests are planned as per the nature of injury and type of pests. Integrated Pest Management (IPM) is an ecosystem approach to crop production and protection that combines different management strategies and practices to grow healthy crops and minimize the use of pesticides.

The presence of insect pest species in a crop does not necessarily mean that control measures are needed. Only when the damage caused exceeds the economic threshold level that these measures should be resorted to. In economic terms it makes sense to apply control measures only if the exercise results in gains greater than the amount spent on these measures.

POLYPHAGOUS INSECT PESTS

Temites, whitegrubs, armyworm and grasshoppers are important polyphagous pests of the arid zone crops. Most kharif legume crops share certain common pests, while some pests share all crop types.

1. Termites

Termites are social insects which cause damage to the stems and roots of young and mature plants which can result in significant plant mortality and yield losses. Termites infest almost all components of arid production systems- crops, grasses, shrubs, trees and even the harvested products (Verma and Joshi 1984, Parihar 1981, 1994). They occur both in kharif and rabi seasons. Basically, they are cellulose feeders. However, all termite activity is not harmful for crops. Some termites may improve soil quality by building tunnels in the ground and improve penetration of air and water into the ground as well as recycling organic matter in the soil.

Termite injury is increased under conditions of water stress. A positive correlation exists between the presence of drought conditions and incidence of attack (Pearce, 1997). Preventive management options viz. soil treatment, seed treatment crop rotation and use of well rotted manure etc go a long way in containing the termite problem. Addition of insecticidal dust in soil at the time of or before sowing is common method used for their control. However, it may be costly. Application of neem, tumba or castor cake has been demonstrated to have a suppressive effect on termite foraging. Addition of chopped Calotropis leaves to soil before sowing is used as ITK in parts of Gujarat and Rajasthan for reducing termite damage. Providing alternative sources of cellulose at sites away from crops are sometimes used to lure the termites and prevent injury to crops. These could be mixed with insecticides or entomopathogens such as Metarrhizium and Verticillium.

Stressed plants are more prone to damage by termites. Healthy, well-grown crops and trees are rarely attacked even though termites may be present. Therefore, improvement of the soil, especially with greater use of compost and green manure, although may not reduce the population of termites but would help in preventing crop damage by providing an alternative source of food. Better organic matter levels, moisture retention and nutrient maintenance in the soil improves root growth and plant production and thus minimises the risk of crop damage due to termites.

2. White grubs

The beetles (order Coleoptera) of family Scarabaeidae are popularly known as chafer beetles or leaf chafers. The term 'white grub' is applied collectively to the larvae of these beetles. The subfamilies Melolonthinae, Rutelinae and Dynastinae of family Scarabaeidae are of agricultural importance. The grubs of these insects are subterranean and feed on the roots of many cultivated and uncultivated plants. White grubs are polyphagous and cause damage to most of the crops cultivated in India during the Kharif season viz., pearl-millet, groundnut, sorghum, cowpea, green gram, clusterbean, etc Yadava, 1991, 2001).

The beetles are attracted to light in the night which could be collected under sources of light and then destroyed manually or mechanically or chemically- by crushing, burning, burying, dipping in insecticidal solution or emulsion of spent oil or kerosene. It is necessary that such operations be carried out on a mass scale. The beetles could also be collected while feeding on the trees, by jerking vigorously the host plants. The grubs could be exposed to predators like birds during ploughing operations. Chemical treatment for the grubs involves high doses of insecticides incorporated in soil in dust formulation before or during crop sowing.

3. Grass hoppers

The grasshoppers damage crops viz., bajra, mung bean etc by nibbling the leaves. Basically, they are pests of grasses but often they shift to the cultivated crops (Parihar 1987, 1995). Grasshoppers can eat 30 to 100 mg of plant material (dry weight) each day. The stage of crop when these pests appear is important and more damage is caused if they appear during the early stage of Locusts also belong to the same category of insects and when in they come in swarms, they cause huge losses. In solitary phase, these insects feed like any other grasshopper species. Unless their population is large, these insects ordinarily do not cause serious injury to the crops. They have a fairly long-life cycle, most species confining to a single generation in a year. The more common species of grasshoppers in dryland crops are *Chrotogonus* sp, *Hieroglyphus* sp, *Oxya* sp, *Atractomorpha* sp, *Acrida* sp and *Pyrgomorpha* sp.

Natural predators of grasshoppers viz., birds, lizards and mantids keep the population of grasshoppers under check but due to the changing scenario of natural ecosystems the population of the predators has dwindled. Diminishing grasslands on the other hand are reducing availability of food resources due to which the problem of damage to crops by these insects is increasing (Singh and Patel 2003). Applying neem formulations to the crops may reduce damage. When injury is severe, use of any contact insecticide could be made in dust formulation. As the grasshoppers lay eggs on the field boundaries, these areas could be deep ploughed during summers to expose the eggs to sun and dehydration bit this practice can aggravate soil erosion due to winds in arid areas.

4. Red Hairy Caterpillars

The red hairy caterpillar, Amasacta moorei also called Katra locally, is a polyphagous pest of sporadic occurrence ((Verma, 1983, Singh and Verma I985). In recent years many farmers of Nagour and Barmer districts have reported attack by this insect in crops especially in clusterbean and bajra.The white coloured moths of this insect with a red lining on the forewings lay eggs on the wild vegetation around the field. After hatching, the larvae feed on the wild plants, before moving to the cultivated fields. The caterpillars move in large bands, devouring any vegetation coming their way, pulses being preferred food. They are voracious feeders and spoil far greater mass of plant material than is required to fulfill their appetite. Development of hairy growth on their body provides protection from predators and also from direct contact of treated surface. In years of epidemic appearance, the entire field is devastated by the caterpillars.

The adult moth of the red hairy caterpillar often lays eggs on the uncultivated plants around the field. Therefore, the weeds around the fields should be removed. Use of light traps is an effective measure against the adults of this pest. If the operations are carried out on community level chances of success are higher. Moving bands of Katra during epidemics could be trapped in trenches. These populations could also be destroyed mechanically. For chemical control, the early instar larvae should be targeted, as the later instar larvae develop the hairy covering, hindering the contact of insecticide with body, and the dose requirement is also increased.

5. Jassids or leaf hoppers

Empoasca spp are important pests of pulses Satyavir (1983b). Empoasca kerri is commonly found on all rainy season crops. Eggs are laid on petioles and veins on the leaf. The young nymphs and the adults feed on the underside of leaves sucking out the juice and injecting toxic saliva into the tissues. Infested plants look unhealthy and lack vigour. Under severe infestation, the leaves curl at the edges and turn brown, giving the field a scorched appearance called hopper burn. Seedling and pre-flowering stages of the plants are more susceptible to jassid attack.

6. White fly

The white fly *Bemisia tabaci* is a small insect, but often occurring in large numbers. It affects the pulses and castor crops, surviving on a wide range of host plants. Eggs are laid on the underside of leaves in a ring attached by a small stalk. The sessile nymphs feed by sucking sap from the leaves, devitalizing them. The adult white fly emerges in 3-4 weeks, depending on the temperature. Winged adults are highly active and like nymphs, feed on the underside of leaf. Severely infested plants show yellowing symptoms, wilting follows and the plant may dry ultimately, if infestation continues unchecked. The flies are vectors of yellow mosaic virus, by far the most injurious disease on moth bean, mungbean and other pulses. The injury inflicted through feeding by white flies, though significant, is considered less important in comparison to the act of YMV disease transmitted by this pest.

7. Aphids

The black aphid, *Aphis craccivora,* sometimes attacks mothbean plants. Once settled on the host, the aphids reproduce both sexually and asexually (parthenogenetically) multiplying rapidly. The colonies may be attended by the ants in return of the honeydew secreted by these insects. Colonies of aphids' suck sap from the underside of leaves, top shoots and stem. The massive loss of sap from plants due to feeding by large aphid colonies results in wilting of plants. The vitality of the plants is greatly reduced. The leaves acquire a curly appearance. The yield of infested crop is greatly reduced. Humid conditions favour rapid multiplication of aphid colonies. When infestation occurs at flowering, the flowers fail to form pods and the developing pods do not produce healthy seeds. The cowpea aphid A. craccivora is reported to be a carrier of leaf crinkle virus.

8. Thrips

The thrips *Megaleurothrips* distalis are small insects with lacerating and licking mouthparts. They feed on leaves, buds and flowers. Plant tissue around the feeding site becomes discoloured, subsequently turning brown and dying if feeding proceeds incessantly. Feeding on floral parts results in deformity of inflorescence and pre mature flower shedding, leading to reduced grain yields.

9. Mites

The mite is a minor pest of pulses, but occasionally it may cause serious losses. *Polyphagotarsonemus latus* is a small pale green mite, difficult to see without magnification. The symptoms of mite damage are leaf discoloration, curling or deformity in leaf and premature leaf drop. Sometimes pods are also affected.

CROPS

1. Pearl Millet: Sima and Srivastava, 2012, surveyed insect fauna in pearl millet crop in Jhujhunu district in western Rajasthan and reported ninety insect species to be associated with this crop. However, damage to this crop by insects is occasional. Pearl millet attracts few regular pests in the arid regions (Verma, 1980). Root grubs and termites affect the crop to limited extent. Red hairy caterpillar Amsacta moorei is a sporadic pest of pearl millet (Verma, 1983). Cylindrothorax and Rhinyptia beetles cause damage to milky and ripening grains (Pal and Sharma, 1973). Satyagopal et al 2014, have reported Cutworm: *Agrotis ipsilon* Hufnagel (Lepidoptera: Noctuidae), White grub: *Holotrichia consanguinea* Blanch (Coleoptera: Scarabaeidae) , Shoot fly: *Atherigona soccata* Rondani (Diptera: Muscidae) and Stem borer: *Chilo partellus* Swinhoe (Lepidoptera: Pyralidae) as insect pests on national significance in pearl millet. They have suggested an AESA based IPM for this crop which is based on entire agro-ecosystem concept, plant health at different stages, built-in-compensation abilities of the plant, pest and defender population dynamics, soil conditions, climatic factors and farmers' past experience. AESA based PHM also results in reduction of chemical pesticide usage and conserves the agro-ecosystems.

2. Arid Pulses and Legumes: The arid pulses and the legumes viz., mung bean, moth bean, cowpea, pigeon pea and clusterbean are attacked by a number of regular and sporadic pests (Singh 1997), The major pests are aphids (*Aphis craccivora*), weevils *Cyrtozemia* spp., flower thrips (*Megalurothrips sjostedti*), white flies *Bemisia* spp, jassids *Empoasca* spp, the pod borer (*Maruca vitrata* syn. *Maruca testulalis*), blister beetles and bugs *Clavigralla*, *Nezara* and *Piezodorus* spp. Different pest management aspects of mung bean have been covered by Singh (1985), Verma and Saxena (1987) and Verma and Henry (1988). Investigations on pest complex of moth bean and cowpea, varietal screening and control aspects were carried by Satyavir (1983a, 1985), Satyavir et al. (1984) and Satyavir and Singh (1985). Foliar damage by leaf weevils and their management has been covered by Singh (1985). The major Insect pests of clusterbean are leaf hopper, *Empoasca motti* Pruthi; whitefly, *Bemisia tabaci* (Genn.), Acaudaleyrodes rachipora (Singh); aphid, Aphis craccivora Koch; pod borer, *Helicoverpa armigera* (Hub.), leaf perforator, *Dichomeris inthes* Meyr and *Maruca testulalis* Geyer; (Singh, 2004)

3. Oilseeds: Sesame and mustard have been the traditional oilseed crops of the arid regions. With the availability of canal water groundnut and castor are also now being cultivated by many farmers. Til leaf and pod caterpillar *Antigastra catalaunalis* is the most destructive pest of sesame in arid regions. The pest attack tolls a heavy loss (25 to 90%) in seed yield (Ahuja and Kalyan, 2002). It

is about 2 cm in length when full grown, pale green in colour and with dark setae all over the body. The caterpillar rolls the leaves together, more frequently the top leaves and feeds on them from within. When pods are formed, it feeds on the developing grains inside, drastically reducing the yield. It may complete several generations before the crop matures. As soon as the damage of this caterpillar is observed, the affected parts should be removed and destroyed, to stop further multiplication of the pest. The crop may be dusted or sprayed with quinalphos. Spraying with Neem seed kernels extract 5% Neem oil 2% (two rounds) is effective during early stages of infestation. Spray of Carbaryl 50 WP 1000 g/ha in 500 litre of water also reduces the population of this pest. Karuppaiah and Nadarajan 2013 have studied host plant resistance against sesame leaf webber and capsule borer, *Antigastra catalaunalis* in 43 sesame genotypes. A good population of lacewing bug larvae was recently observed at organic farm at CRF CAZRI which reduced the population of *Antigastra* significantly.

Til hawk moth *Acherontia styx* is another damaging pest of sesame. The caterpillars of *A. styx* feed on leaves of sesame and sometimes on moth bean also. The full-grown caterpillars are stout, greenish with dark green oblique lines on the sides, measuring up to 10 cm in length. Though few in numbers, they consume considerable foliage, in proportion to their body size.

The caterpillars could be handpicked, as these are easily located, and destroyed. The caterpillars pupate in soil. The soil could be ploughed to expose the pupae to predators and sun. For chemical control potent stomach and contact poisons like quinalphos, methyl parathion could be used. The eggs laid singly on leaves are parasitized by *Apanteles* spp and some tachinids.

Many insects are associated with the Brassica oilseed crops. The most damaging ones are mustard aphid, *Lipaphis erysimi* (Kalt.), mustard sawfly, *Athalia proxima* Klug., and painted bug, *Bagrada hilaris* Kirk. Mustard aphid, *L. erysimi* is one of the most destructive insects which is responsible for causing severe reduction in seed yield varying from 15.0 to 73.3% (Bakhetia and Sekhon, 1989)

White grubs and termites, are the major groups of soil pests that are widespread and of economic importance in groundnut production (*Arachis hypogaea* L.) (Wightman and Amin 1988, Prasad and Rathod 2008). *Spodoptera litura* Fab. and the groundnut leaf miner *Aproaerema modicella* Deventer have been reported as the major above ground pests (Wightman and Amin 1988). Aphids transmit a number of virus diseases. A thrip *Frankliniella schultzei* (Trybom) is the vector of bud necrosis disease, which is a serious problem Jassids also occasionally cause much foliar damage and may also act as virus vectors.

The pest control measures available are mainly chemical pesticides which are too expensive and cause environmental pollution. In integrated pest management (IPM) modules, emphasis is on the use of resistant groundnut varieties, cultural practices, botanicals and minimal application of synthetic insecticides. Intercrops such as pearl millet and soybean suppress thrips, jassids and leaf miner; castor suppresses jassids and Spodoptera. These plants act as traps or barriers for reducing pest incidence. Soil application of phorate @ 25 kg /ha or spraying of chlorpyriphos 1 kg a.i. / ha is done to control pests like white grub and termites.

Bio-intensive module for management of major insect pests of groundnut was studied by Baskaran et al 2014. They found bio-intensive module for groundnut [vermicompost 2 t/ha + neem cake 250 kg/ha + bio-fertilizers 2 kg/ha + NPK (8.5:34:54 kg/ha); *Chrysoperla zastrowi* @ 50,000 eggs/ha (3 releases on 20, 30, 40 DAS); *Trichogramma chilonis* + *T. japonicum* @ 6.25 cc/ha (3 releases on 37, 47, 57 DAS); *Helicoverpa armigera* NPV and *Spodoptera litura* NPV @ 500 ml/ha (4 sprays 40, 50, 60, 70 DAS); neem gold 0.15% @ 1.5 ml/lit (4 sprays 25, 40, 55, 70 DAS)] was effective in reducing the incidence of both the sucking pests (aphids & leafhopper) and defoliators of groundnut and recorded the highest yield.

Castor is an important oilseed crop of arid and semi-arid regions. Insect pests and diseases are responsible for more than 25% losses in castor. (Basappa 2003). The major insect pests of castor are castor semilooper, *Achaea janata* Linn. Castor Shoot Borer, *Dichocrosis punctiferalis* and jassids (DOR 2003).

Intercropping is an important cultural practice in pest management and is based on the principle of reducing insect pests by increasing the diversity of an ecosystem .The diversity created by introducing cluster bean, cowpea, black gram, or groundnut as intercrops in castor (1:2 ratio proportions) resulted in reduction of incidence of insect pests, namely semilooper (*Achaea janata* L.), leaf hopper (*Empoasca flavescens* Fabricius), and shoot and capsule borer (*Conogethes punctiferalis* Guenee). A buildup of natural enemies (*Microplitis, coccinellids*, and spiders) of the major pests of castor was also observed in these intercropping systems and resulted in the reduction of insect pests (Rao et al., 2012). Satyagopal et al 2014, have suggested the use of resistant varieties, intercropping, spraying of *Bacillus thuringiensis* var *kurstaki* @ 400 g in 200-300 l of water/acre or spray of neem seed kernal extract (NSKE) 4% synchronising with egg oviposition and early larval stages, need base spray of malathion 50% EC @ 800 ml in 200-400 l of water/acre or dimethoate 30% EC @ 462 ml in 200-400 l of water/acre for control of Castor semilooper. Intercropping with cluster bean, cowpea, black gram, or groundnut (1: 2 ratio proportions) has been found to reduce semilooper infestation and build up natural enemies.

PESTS OF HORTICULTURAL PLANTS

1. Fruit flies: The fruit flies are the most important pests of fruit crops. The maggots of these flies feed on the fruit pulp, leaving excreta and causing rotting, thus spoiling the produce or reducing its market value. Dacus spp respond to lures like protein baits and methyl eugenol, which could be used for collection and destruction of the flies.

On jujube the ber fruit fly, *Carpomyia vesuviana* is major pest. Different cultivars respond differently to its attack. Varieties like Tikadi and Ilaichi contract low fly incidence, which may be adopted for cultivation. Lines with low fruit fly incidence, good fruit size and early maturity have been developed at CAZRI, which could be propagated. The maggots of the jujube fruit fly come out of the fruits for pupation in soil. Their movement in soil could be restricted through barriers like polyethylene sheet below the bush. The practice will also expose the maggots to natural enemies like birds and the braconid parasites. Alternatively, incorporation of dust formulation of contact insecticide in soil at this stage will expose larvae heading for pupation. Exposure of the pupae to sun during hot summer months serves to reduce the number of emerging flies in the next season.

The activity of *C. vesuviana* coincides in part with those of the insect pollinators, which play a vital role in fruit setting. However, the flies oviposit in the fruit after these have attained the size of pea. By the time the early set fruit attain this size, about three fourth of fruit set in the early maturing cultivars is over. Use of insecticide can be made at this stage. Of the many spray schedules evaluated at CAZRI, the one involving first spray of chloropyriphos (0.05%) in mid October, second of the same insecticide or of quinalphos three weeks after the first spray proved effective against the fruit fly. Effectiveness of some systemic insecticides has also been reported.

2. Bark eating caterpillar: It affects all woody fruit plants. They feed on the bark during night, remaining concealed during daytime in the tunnel made at the junction of branches. The junction point is rendered weak due to tunnel. During the bearing period when fruits develop, pressure at the forks is greatly increased due to weight of fruits, resulting in cleavage of the branch at the fork or angle and its drying. Thus, a single larva can spoil the produce of the entire branch.

Infestation of the bark-eating caterpillar is easily detected by the presence of frassy webs at the forks or angles. After detection, destruction of the caterpillar is not difficult; it can be easily killed by inserting an iron spike in the hole of the caterpillar. However, in bigger orchards, treatment is required. Insecticides may be applied on affected plants by painting or spraying around the feeding site of the caterpillar, by injecting the insecticidal solution in the hole through a syringe; or by inserting cotton swabs dipped in insecticide. For painting or spraying around the feeding site, quinalphos (0.05%) could be used, while for cotton swabs and injection, dichlorvos could be chosen. The treated holes should invariably be plugged with mud or clay to prevent escape of the larva and to ensure its exposure to insecticide.

3. Chafer beetles: On khejri, 33 insect species have been reported from arid tracts. Several insects are reported to be associated with khejri (*Prosopis cineraria*). (Parihar 1993, Parihar and Singh (1998). After the rains, chafer beetles defoliate the fruit plants heavily. Although their stay on host plant is limited, because of their voracious nature, much of foliage is damaged. The beetles could be collected during late evening by jerking the plant and destroyed by immersing in water containing insecticide or oil emulsion. The well-known tendency of the chafers of getting oriented towards source of light at night may be exploited for collecting the beetles under light traps. However, this method needs to be adopted with caution, as isolated efforts often lead to accentuated chafer population in the vicinity of light traps. Light traps, therefore, should be erected in large numbers and scattered, on a co-operative basis.

Eurytoma sp. cause gall formation in *P. cineraria*. *Eriophyes prosopidis* is responsible for formation leaf and inflorecence galls on *P. cineraria*. *Acanthophorus serraticornis* is a major cause of premature drying of khejri trees (Kumar, 1999. Singh et al., 2001).

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NEMATODE PROBLEMS AND THEIR MANAGEMENT IN HORTICULTURAL CROPS OF ARID REGION

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NEMATODE DISEASES

Most of the nematode problems in arid region are observed on crops grown under assured irrigation. Though surveys of rainfed crops have revealed the presence of a number of plant nematodes on various crops but their population builds up during rainy season and decreases with the withdrawal of the monsoon. In rainfed crops *Heterodera cajani* and *Meloidogyne javanica* and *M. incognita* on pigeon pea and *M. javanica* and *M. incognita* on mungbean are of common occurrence. Amongst the various crops grown under irrigated conditions, nematode damage is mostly observed on horticultural crops (vegetables and fruit crops) and spices. The disease symptoms caused by nematodes are often similar to those produced due to the deficiency of nutrients. Unthrifty or stunted growth of crops in patches is often indicative of nematode attack. Root-knot nematode, reniform nematode, root-lesion nematode and stunt nematode are the most common plant nematodes parasitizing horticultural crops in arid zone.

VEGETABLE CROPS

Root-knot nematode (*Meloidogyne* species)

Symptoms: Infected plants show stunted growth. Foliage turns yellow green to yellow. Plants may wilt easily in dry and hot weather. The most characteristic symptom of the disease is the formation of galls or knots on the root system. Gall size may vary according to the host plant or nematode species involved. Sometimes cracks may appear on the galled roots which may lead to infection by secondary microorganisms especially fungi, bacteria and saprophytic nematodes. Practically all the vegetable crops are affected by one or the other species of this nematode. The common *Meloidogyne* species attacking the vegetable crops are *M. incognita*, *M. javanica*, *M. arenaria*, *M. hapla*.

Biology: Second stage larva is the infective stage of this nematode. Larvae enter the roots and feed on the vascular tissues and undergo development to become adult female or male. The nematode is an endoparasite of the roots. The females of the nematode are obese in shape and lays eggs in mucilaginous egg masses mostly outside the roots. The nematode completes life cycle in 25-30 days and within a crop season nematode may complete two or more generations. The number of eggs/egg mass may vary from 150-400.

Reniform nematode (*Rotylenchulus reniformis*)

Symptoms: Plants show poor growth. Leaves turn pale yellow and are smaller in size. Fruit size is reduced which results in decrease in the yield. Like root-knot nematode this nematode is also polyphagus in nature and is known to parasitize most of the vegetable crops. This nematode often occurs with root-knot nematode and depending upon the population level, it may cause even more damage than root-knot nematode.

Biology: Young female feed on root tissues. Instead of entering roots completely, the anterior portion of the nematode enters the roots while the posterior portion remains outside the roots. The nematode remains sedentary in position and while attaining maturity the posterior portion of the body becomes swollen and the nematode appears kidney form in shape. This nematode is a semi endoparasite of roots. Female lays eggs in gelatinous matrix out side the roots. Nematode takes 3-4 weeks to complete the life cycle.

Root-lesion nematode (*Pratylenchus* species)

Symptoms: This nematode is a migratory endoparasite of roots. Usually outer tissue of root is destroyed by the nematode. The nematode causes necrosis of roots. During early infection of roots, small brown lesions are formed. The lesions are elongate and narrow in shape. Later the lesions merge together to form necrotic patches. Heavy infection by nematode may lead to drastic reduction of root system. Foliage of plant shows chlorotic symptoms. High population of this nematode may result in the death of the plants.

Biology: Juveniles as well as adults are the infective stages in this nematode. Once the nematode enters the root tissue, it feeds on the cells. As a result of nematode feeding, toxic chemicals like HCN and benzyldehyde are produced. This results in the death of tissues. The nematode being unable to feed on these cells migrates to healthy tissues. The death of the tissues and migration of the nematode from one place to other results in the formation of lesions having tunnel like structures.

Stunt nematode (*Tylenchrohynchus* spp.)

This nematode is an ecto-parasitic nematode. Generally high population of the nematode cause reduction in the root system and the plants exhibit stunted growth with chlorosis of foliage.

Management

As the nematodes parasitizing vegetable crops are root feeders and pass major part of their life cycle in soil/ roots, therefore most of the control measures for the management of the nematodes are targeted on soil.

- In case of transplanting crops, it is advisable to raise nursery in nematode free soil.
- Arid regions experience high temperatures during summer months, soil solarization of nursery beds using polythene sheets (25-50 µm) for 15 or more days reduces nematode population to a great extent. Light irrigation of soil followed by soil solarization is more efficient in causing drastic reduction of nematode population.
- Treatment of nursery beds at the time of sowing with carbofuran @ 0.3 g a.i./m2 + neem cake @ 500 kg/ha reduces nematode infection and helps in raising healthy planting material.
- If the soil is heavily infested, application of carbofuran to soil @ 1-2 kg a.i./ ha before transplanting followed by root dip treatment to seedlings of with carbosulfan (25 EC) @ 500 ppm at the time of transplanting in the field greatly reduces the infection by the nematode.
- As an alternative to chemical treatment at the time of transplanting in case of chilli, dipping root in soil paste containing 4-6 spores of AM fungus, *Glomus fasciculatum* effectively reduces root infection by the nematode.
- In nematode infested field, deep ploughing 2 times at an interval of two weeks during summer months (May and June) results in the drastic reduction of nematode population in the soil.
- Use of organic amendments including neem, mustard and castor cakes @ 1 ton/ha has been found to reduce root-knot nematode.
- In case of direct seeded vegetables, solarization of nematode infested field coupled with seed dressing with carbosulfan (25 DS) @ 3% a.i. (w/w) reduced the attack of root-knot, reniform and lesion nematodes.
- Repeated cultivation of host crops in the same field should be avoided as it leads to the buildup of nematode populations. Rotation with non-host crops often results in the reduction of nematode population. For root-knot and reniform nematode it is advisable to rotate vegetables with cereals and millets. Use of non-host crops like mustard, garlic, onion and cereals at least for 2 to 3 years in a suitable cropping system helps in controlling the nematode.
- Use of tomato resistant varieties like Hisar Lalit, Punjab NR 7 and SL 120 etc. may be used in root-knot nematode-infested areas.

NEMATODE PROBLEMS OF FRUIT CORPS

Citrus

Symptoms: *Tylenchulus semipenetrans* is the major nematode pest of citrus. The nematode causes slow decline of citrus. Affected trees are generally stunted with little bearing and exhibit die back of twigs. Foliage is spares often dull grey green or bronze green in colour. Leaves are smaller than normal size and roots of such trees are dark in colour with shortened rootlets which often become swollen and irregular in appearance.

Biology: This nematode is a semi-endoparasite of roots. Young female is the infective stage of this nematode. Nematode deposits eggs in mucoid masses. It takes about 4 weeks to complete the life cycle.

Management: Certified root stocks of citrus free from nematode should be used. Infected root stocks can be treated with hot water at 46.7oC for 10 minutes or at 45oC for 25 minutes. *Poncirus trifoliata* is a resistant root stock against this nematode.

Pomegranate:

Symptoms: Root-knot nematode (*Meloidogyne* sp.) is most important nematode pest of this crop. Diseased plants exhibit poor growth. Heavy infestation by the nematode often leads to the chlorosis of the foliage and during summer months, drying of twigs may also be observed. Nursery infected pomegranate plants are often difficult to establish when transplanted in the field. Roots infected by this nematode show small to large galls.

Management: The nursery plants should be raised in nematode free soil. Application of carbofuran (3G) at the rate of 15-25 gm. per plant as a basin treatment to three-year-old plants helps in managing this nematode.

Soil application of two tons of FYM or 500 kg of neem cake/Pongamia cake or one ton of vermi-compost enriched with *Pseudomonas fluorescens* + *Trichoderma harzianum* + *Paecilomyces lilacinus* at the time of land preparation has been found effective for the management of root-knot nematode.

Similarly, application of *Phule Trichoderma* plus (*T. viridae*+ P. lilacinus) (1x106 cfu/g) @ 10 kg/ha (14 g/plant) at the time of bahar and 10 kg/ha again at 90 days after bahar (14 g /plant) by ring method along with 100 kg moist decomposed farm yard manure has also been found to manage the root-knot nematode caused disease in pomegranate under field conditions.

LAND USE-LAND COVER MAPPING, CHANGE DETECTION AND HUMAN-WILDLIFE CONFLICT ANALYSIS USING GEOSPATIAL TECHNOLOGY: A CONCEPTUAL FRAMEWORK

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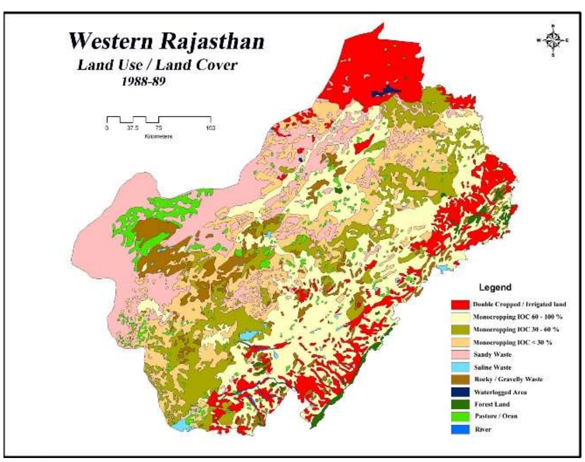
INTRODUCTION

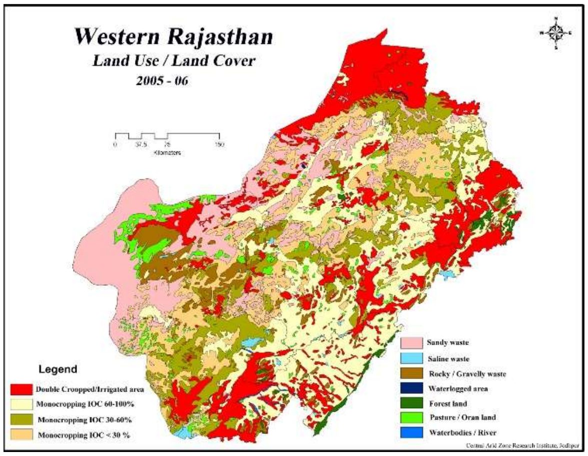
Human-wildlife conflict (HWC) is fast becoming a critical threat to the survival of many globally endangered species, in particular to large and rare mammals especially in the scenario where habitat loss is rampant and human populations are surging. The numerous cases from countries all over the world demonstrate the severity of human-wildlife conflict and suggest that an in-depth analysis is essential to understand the problem and support the conservation prospects of threatened and potentially endangered species. One of the most frequent form of conflict reported, is the large carnivore predation on domestic livestock. This conflict has implications on conservation of biodiversity and tolerance of humans towards wildlife. There has been a marked increase in the use of remote sensing and geospatial technologies to monitor the land use changes and have an important role in study of biodiversity as well as in determination of natural resources and wildlife monitoring.

Land use and land cover

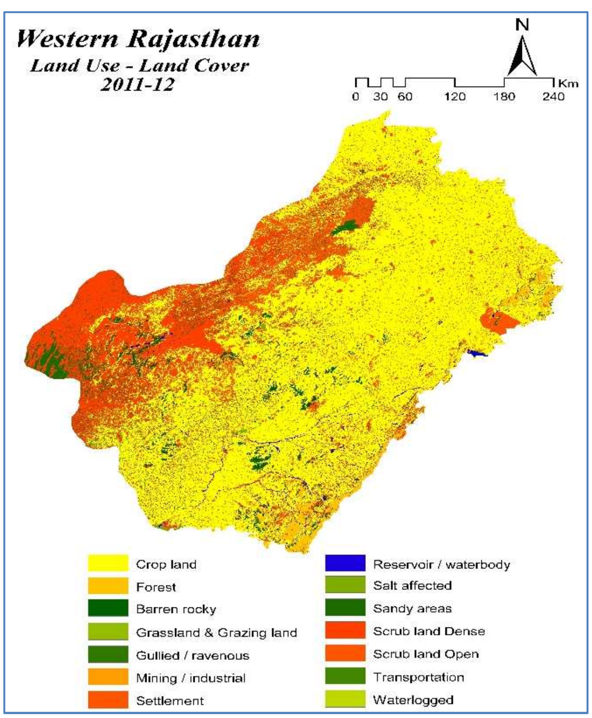
Land use and land cover is an important component to understand global land status; it shows present as well as past status of the earth surface. Land use and land cover are two separate terminologies which are often used interchangeably (Dimyati et al 1994). Land cover is a basic parameter which evaluates the content of earth surface as an important factor that affects the condition and functioning of the ecosystem. Land cover is a biophysical state of the Earth surface, which can be used to estimate the interaction of biodiversity with the surrounding environment. Nowadays, land use land cover analysis plays an important role in the field of environmental science and natural resource management. The land cover reflects the biophysical of state of the earth's surface and immediate surface, including the soil material, vegetation and water. L and use refers to



utilization of land resources by human beings and land cover changes often reflects the most significant impact on environment due to excessive human activities. Land use and land cover is dynamic in nature and is an provides a comprehensive understanding of the interaction and relationship of anthropogenic activities with the environment (Prakasam, 2010). Land use/cover changes also involve the modification, either direct or indirect, of a natural



habitat and their impact on the ecology of the area. Land use/cover change has become a central component in current strategies for managing natural resource and monitoring environmental changes (Tiwari and Saxena, 2011). Land use/cover pattern of a region gives information about the natural and socio-economic factors, human livelihood and development. Like other resources, land resource is also delimiting due to very high demand of agricultural products and increasing population pressure day by day. Hence, information of land use/cover and possibilities of their optimal use is essential for the selection, planning and implementation of the land use schemes to meet the increasing human needs and welfare. This also provides the information for managing dynamics of land use and meeting the demands of increasing human population.



Change detection is the process of identifying difference in the state of an object or phenomenon by observing it at different time (Anderson, 1977).Change detection in Land use/cover can be performed on temporal scale such as decades to assess landscape changes caused due to anthropogenic activities on the land (Gibson and Power, 2000). These anthropogenic activities are due to rapid growth of human population and demands of food resources. Land use land cover changes have been recognized as important drivers of global environment change (Turner et al 1996). High temporal resolution, precise spectral bandwidths, and accurate geo-referencing procedure are factors that contribute to increase use of satellite data for change detection analysis (Jensen, 1996). Processing of multi-temporal images and change detection techniques has been developed in the past three decades. Change information of the Earth's surfaces is becoming more and more important in monitoring of the local, regional and global environment.

The forest connectivity and corridors are critical for biodiversity conservation. A wildlife corridor is a narrow strip of forest cover, connecting two larger forest areas. These corridors help in dispersal and movement of individuals between different habitats for food, folder, shelter, breeding and other activities. Corridors connect habitat patches for the exchange of materials and energy in the form of food web and dispersal and genetic exchange (Vogt et al., 2007). Degradation of forest connectivity in between landscapes occurs due to fragmentation and anthropogenic activity, which causes biodiversity decline. Conservation of wildlife corridors requires a complete knowledge of species habitat requirements. It also requires past and current area under different land use practices such as agriculture, forestry and human habitations that alter vegetation cover, land surface, biochemistry, hydrology and biodiversity (Ellis 2007). Vegetation forms an integral component of terrestrial ecosystem and wildlife habitat (Khanna et al. 2001). Information of land use/cover and conflicts supports the assessment of wildlife habitat and identification of corridor status.

HUMAN-WILDLIFE CONFLICT

Human - Wildlife Conflict (HWC) is defined as 'interaction between humans and wildlife where negative consequences, whether perceived or real, exists for one or both the parties when action of one has an adverse effect on the other party' (Conover, 2001; Decker et al., 2002). It has been in existence for as long as wild animals and humans have co-existed and shared the same resources. The growing human population, deforestation, loss of habitat and decline in their prey species are few major reasons behind the Human wildlife conflict in India. Natural wildlife territory is overlaps with the human's existence and various forms of human–wildlife conflict occurs with various negative results. The intensity of the problem is increasing because of a number of factors such as increase in human populations, anthropogenic encroachment into wildlife habitats resulting in transformation of wildlife habitats into urban and sub-urban areas and agrarian ecosystems and fragmentation of wildlife habitat causing constriction of wildlife populations into marginal habitat patches (Siex and Struhsaker, 1999). Recovery of declining populations of many large mammals due to efficient wildlife management and large network of protected areas worldwide has also led to increased conflicts (Saberwal et al., 1994).

The increasing population of certain species raises the frequency of conflicts unless community support and space is ensured. There are 30,000 elephants in India, and 2,226 tigers. India has aimed to double the number of tigers and that strategies are being drafted to manage tiger-human conflicts.

India is a mega-diverse country owing to its large climatic and topographic gradient. With only 2.4% of the world's land area, it harbours around 8% of all recorded species including 91,000 species of animals and 45,000 of plants (MoEFCC, 2014). Out of 34 global 'Biodiversity Hotspots', four falls fully or partly within Indian political boundaries. With more than 100 National Parks and more than 500 Wildlife Sanctuaries, the country has an extensive network of protected areas and wildlife reserves. In 2017, the Wildlife Institute of India recorded 31 leopards across five districts in Haryana (including Gurugram), a fourfold increase in population since 2012, when a similar survey estimated that there were just eight leopards in the same area (measuring a little over 120 square kilometers). In 2018, a drone mapping survey by the forest department reported the presence of 35 leopards in Gurugram itself.

Conflict incidents related to crops, property and livestock account for 94% of losses in wildlife conflict and 72% of payments. These could be reduced by integrating early warning systems with simpler damage-prevention practices (such as improving fencing of crops or better livestock husbandry) in conjunction with simpler and more efficient processing of claims.

Reason behind the human interaction are as follows:

- Deforestation
- Loss of habitat
- Decline in prey
- Injured or old animal
- Growing human population

Following are the results of human wildlife conflict

- Crop damage
- Animal deaths
- Loss of human life
- Injuries to people
- Injuries to wildlife
- Livestock depredation

Probable solutions to reduce human interaction and wildlife conflict are as follows:

- Fencing
- Land-use planning
- Livestock protection
- Avoid stepping out after dark

Mitigation of human-wildlife conflict is thus becoming one of the key issues of concern for both wildlife managers and the scientific community. There is a need to create an enabling environment for them to address the situation, and to strengthen their capacities in the most efficient and effective manner.

Management of Human wildlife conflict in India is an urgent and important issue. It is necessary to address the issue in a holistic manner, and co-create the mitigation solutions, with full engagement of all the relevant stakeholders.

GEOSPATIAL TECHNOLOGIES

Remote Sensing and Geographical Information System (GIS) provides a modern foray into the issues of ecosystem management. The technique has been used extensively in the tropics for generating valuable information on the forest cover, vegetation type and land use changes (Forman, 1995). Now, advanced geospatial technologies have further improved the efficiency of mapping of land use land cover type at landscape level. Thus, integration of these tools/ techniques such as Geographic Information System (GIS), Remote Sensing (RS), Global Positioning System (GPS) are realized as complimentary systems to ground-based studies. These forms a potential tool for land use land cover and change detection.

GIS technology is an effective tool for managing, analysing, and mapping wildlife data such as population size and distribution, habitat use and preference, changes in habitats, and regional biodiversity. It is used for collating, analysing, updating and managing data in wildlife management or research projects. It acts as a computerised database management tool that offers solutions for planning, problem analysis and monitoring wildlife. The patterns and processes occurring in a geographic space or landscape that influence characteristics of plant and animal populations such as densities, distributions and movements is effectively studied using geospatial information and field-based observations.

Satellite Remote Sensing and GIS for Natural Resource Management

Remote sensing and Geographic Information System (GIS) have emerged as powerful tool for planning and decision support in the area of natural resource mapping, monitoring and management. Satellite-derived data products are attractive for monitoring because of the synoptic view of the landscape they provide. A host of products are available for the contiguous areas that address tree cover, but each has limited utility with regard to narrow linear plantings, or sparse cover, such as pasture or rangeland with trees.

A chief use of remotely sensed data is to produce a classification map of the identifiable or meaningful features or classes of the land cover types in a scene. In the field of remote sensing, image classification is a process in which pixels or the basic element unit of an image are assigned to classes. By comparing pixels to one another and to those known identity, it is possible to assemble groups of similar pixels into classes and produce a thematic map. Image classification is defined as the process of creating thematic maps from satellite imagery (DeFries et al. 1999). A thematic map is an informational representation of an image which conveys information regarding the spatial distribution of particular theme say vegetation (Campbell and Hofer, 1995). The objective of image classification is to classify each pixel of an image into land cover categories.

The resolution of imagery selected for monitoring should be appropriate to the features to be observed. There are many examples of high-resolution imagery used in natural resource monitoring applications of small targets. Laliberte et al. (2004) used Quick Bird imagery (61-cm panchromatic and 2.4-m multispectral) to assess shrub encroachment.

Acquirement of remote sensing images of earth from space has opened up new frontiers for conservation and management of biodiversity. The multispectral satellite images provide definitions of vegetation patches, which are related to phonological types, gregarious formations and communities occurring in unique biodiversity setup (Behera 1999). The temporal satellite images provide information for vegetation mapping, monitoring and understanding ecosystem functions, primarily through the relationship between reflectance of vegetation structure and composition (Joshi et al. 2003). Landsat Multispectral Scanner (MSS), Thematic Mapper (TM) and Enhanced Thematic Mapper Plus (ETM+) data have been broadly employed in studies towards the determination of land cover since 1972, the starting year of Landsat program, mainly in forest and agricultural areas. Indian satellite data like IRS-1B, 1C, Cartosat series, RISAT, Resourcesat Series, and many more from various other countries provide high resolution data (Gaur 2016). The rich archive and spectral resolution of satellite images are the most important reasons for their uses. Such an approach allows monitoring the forest condition and degradation processes of earth surface. The images also provide digital mosaic of the spatial arrangement of land cover and vegetation types amenable to computer processing and difference in surface phenomenon over time can be determined and evaluated by visual interpretation with local knowledge (Garg et al. 1988). The other approach to analyse the conservation and management of biodiversity is based on nominal scale classified maps of remote sensing imagery. These maps can also be analysed using various indices quantitatively, which measure the heterogeneity of biodiversity within a specific radius. Diversity and dominance are well known examples of those indices (Baker and Cai, 1992). They are ordinarily computed from samples of relatively homogenous cover types, named patches. Size, shapes, perimeter, connectivity, orientation, presence of corridors, visibility or diversity of patches are critical variables for describing the biodiversity mosaic.

Geographic Information Systems (GIS) are tools for acquiring, managing, analysing and visualization of spatially explicit information. GIS transform varied datasets into easy-to-read and easy-to-access maps and generate required information. In addition, the advantages are numerous. GIS architectures have traditionally focussed on a static environment in which users perform spatial analysis. Further, GIS offers a sound technical approach for documenting, monitoring, and evaluating the impact of agricultural farming activities. GIS is an essential tool that can be used to offer effective support for spatial planning and decision making while addressing these issues. There is an abundance of reliable technologies and spatial data that significantly widens the scope of potential GIS applications. "Geographic information systems integrate seemingly disparate information quickly and visually, which facilitates communication, collaboration, and decision making" (Tomlinson 2007). Ellis, Bentrup and Schoeneberger (2004) discusses the development of decision support tools (DSTs) including GIS in agroforestry.

GIS has been applied to the management of agroforestry practices in various parts of the world in a wide range of agro-ecological regions from tropical to temperate. The use of information systems in agroforestry began with development of databases to aid in guiding plant selection. With the changing needs, improved technologies, and data proliferation, their application has evolved to monitoring, precision farming, and modelling different systems and predicting outcomes of different scenarios (Ellis, Bentrup and Schoeneberger, 2004).

The perpetual advancements in technology and availability of more information about agroforestry systems have seen not only the rise of internet-based GIS, but also better functionalities to meet the needs of diverse audiences. These applications range from simple demonstrations and references to GIS use, to complex geoprocessing tools used to solve spatial problems and support decision making. The internet is affecting GIS in three major areas of GIS data access, spatial information dissemination, and GIS processing and analysis.

Geographic information system (GIS)

Geographic information systems are used to collect, store, analyse, disseminate and manipulate information that can be referenced to a geographical location. It provides the way to overlay different 'layers' of data like the ecological conditions, the actual vegetation physiognomy and human pressure indices and helps to assess disturbance levels; the spatial distribution of several species in order to determine biodiversity status; past and present maps for monitoring land cover and land use changes. The most widely used definition of GIS is a computer-based system that captures, stores, manages, analyses, and displays geo-referenced data (geographic data). It provides possibilities to extrapolate observations e.g., to automatically define and map the potential area of a given species and to compare it with the locations where, it has been actually observed; or to combine different data sets for defining the potential list of species for a given forest type. GIS provides a database structure for efficiently storing and managing ecosystem related data over large regions. It also assists in location of study plots and ecologically sensitive areas. GIS supports spatial statistical analysis of ecological distributions. It improves remote sensing information extraction capabilities, and provides input data and parameters for conservation and management of biodiversity.

Global positioning system (GPS)

Global positioning system has received much attention in the past several decades, due to their broad appeal across a wide spectrum of both industry and research. It is a satellite-based positioning system. GPS allows the collection of information about the geographical position of any location using a network of satellites. It has a great potential in conservation and management of biodiversity, as well as in many other disciplines related of biological study which requiring geographic locations of the objects. Integrating with GIS, it acts as a powerful tool to describe the geographical characteristics of ecological systems. A practical use of GPS has been in locating the sample plots and this information was used for mapping and spatio-statistical analysis (Behera et al. 2000).

MONITORING OF WILD ANIMALS

The kinds of systems in use are described under six categories, which are used to show the most common technological systems in use. These include patrol visualization tools, GPS trackers, sensors, drones, acoustic monitoring systems and camera traps.

Patrol visualization tools are commonly used to improve patrol efforts by concentrating ranger movements in high-risk locations. These tools primarily rely on GPS tracking of both animals and rangers and geo-referenced coordinates of animal carcasses and other important information, such as sightings of poacher activity. The tool relies primarily on two types of data: geo-referenced location of animal carcasses and ranger patrol information e.g. routes, time and length of patrol. There is a choice of two formats depending on the capabilities and resources of the user group; either a paper-based workbook that can be freely downloaded or a Geographic Information System (GIS) based system called the Spatial Monitoring and Reporting Tool (SMART). The interactive map provides a point of review so that decisions regarding ranger patrol routes can be made in an informed manner.

GPS trackers have commonly been attached to wildlife in the form of collars, ear tags or embedded under an animal's skin. This is used to monitor movements e.g. bird migrations. Various private companies around the world are developing these tracking devices e.g. savannah tracking, telemetry solutions, biotrack, sirtrack etc. In order to visualize wild animal movements GPS trackers are attached to the animals and movement data are uploaded into the Google Earth platform. This then shows a simulation of their movements, the movement range, frequented routes etc. This tool can be used to assist in the design of ranger patrol routes and allows knowledge acquisition of how wild animals respond to land use and land cover change.

Sensors are used in many of the initiatives listed in the database. One example is an NGO called Wildland Security who developed a system called 'Trail Guards'. This system offers surveillance of paths into vulnerable conservation areas and consists of concealed electronic sensors triggered by the motion of a large animal or by metal detection e.g. poachers carrying rifles or machetes. Fire detectors have also been installed and hidden in the trees as poachers often smoke meat before taking it to market. Once the sensors are triggered rangers are alerted and given the GPS co-ordinates of the event via satellite phone.

Camera Traps have long been used in conservation for the purpose of security, creating species inventories and monitoring conservation measures, etc. Camera traps are camouflaged and hidden in the canopy. Once triggered by movement, they turn on and send an alert to rangers via satellite with the intruder's coordinates. This compliments the ground and infrared sensors of poacher movement.

UAVs (drones) also work as camera traps, often using infrared and thermal imaging to detect wildlife and humans around the clock over vast distances. The cameras can be mounted onto UAVs or low-speed reconnaissance aircraft.

Acoustic Monitoring is a tool used to track animals and poachers. To combat wildlife crime a technology called 'shotgun sensor' is used which locates the geo-position of a gunshot so rangers can spot and arrest culprits. This technology is only useful for poaching incidents where guns are used. It has proven successful for police forces in the US, accurately locating crime spots.

Application of Geospatial Technologies

However, advancement in the spatial and spectral resolutions of sensors are now available to conservation biologist, which is making the direct use of remote sensing at certain aspects of biodiversity starting from distinguishing species assemblages or even identifying species of individual trees. In the recent decades, with the increase in the number of earth observation satellites with better repetitively, improvement in spectral bands, wide range of spatial resolutions and unprecedented number of remote sensing tools enable the management authority for proper management and conservation of biodiversity.

Table: Data layers useful in a decision support system

Category	**Data layer**
Administrative	– State boundary – District boundary – Block boundary – Study area boundary – Nearby cities, towns, villages, (points & polygons) – Weather stations – Community / Government property / open land – Topographic maps 1:50,000 or 4,000 scales – Transport network (line) – Infrastructure facilities such as buildings, pipelines,

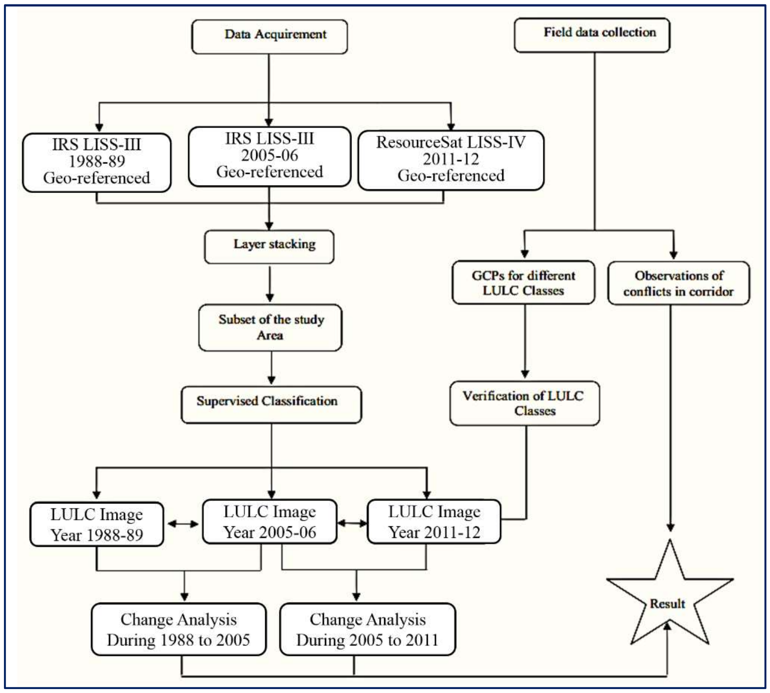
	and special features (man-made)
Hydrology	– Hydrologic unit boundaries – Drainage area – Stream order – Stream bed elevation
Topography	– Topographic maps 1:1 million, 1:50,000 or 4,000 scales – Shaded relief – Physiographic units – Digital Elevation models
Remote Sensing	– False Colour/ True Colour georeferenced satellite images (optical & infrared)
Land Use-Land Cover	– Current & historical vegetation maps – Flood Zones – Grasslands/Grazing lands – Crop land – Forest (protected, open, conserved, scrub, etc.)
Geology/Soils	– Soil Maps – Wind & Water Erosion – Land Degradation maps
Nutrients	– Ammonia – N Concentrations – Nitrated – Phosphorous
Biology	– Plant & Animal Surveys

Materials and Methods

Changes in vegetation pattern are detected using various satellite FCCs, owing to their good spectral and temporal resolution and moderate spatial resolution (Lillesand et al 2004). Apart from Google Earth Imagery and Survey of India toposheets with scale of 1:50,000 are used for vector layer creation. For carrying out such a kind of studies following satellite data and software's are often used: -

Satellite date		Software	
Cartosat LISS-IV	Sentinel	ArcGIS	Erdas Imagine
IRS LISS-III	WorldView	QGIS	

The Normalized Difference Vegetation Index (NDVI) of common vegetation habitats and rainfall patterns were also explored. NDVI, is the most commonly used index of greenness derived from multispectral remote sensing data, and has been used in many studies on vegetation, where it has been proven to be positively correlated with density of green matter. Over the last decade, numerous studies have highlighted the potential role of satellite data in ecological studies, in particular the use of Normalized Difference Vegetation Index. Recently, the use of NDVI-based indices linked to animal distribution and abundance has been emphasised.



Workflow Diagram

CONCLUSION

Three primary approaches are commonly used for mapping human-wildlife conflict: correlation modelling, spatial association and spatial interpolation. Quantitative, scientific tools are a critical part of wildlife management (Sinclair 1991). Many spatial software use correlation modelling to predict gradients of animal interactions relative to spatially explicit environmental or anthropogenic variables. Yet despite the serious ramifications of wild animals' attacks for local livelihoods and wild life conservation, surprisingly few quantitative techniques exist to assist stakeholders, managers and policymakers in understanding and mitigating human– wild animal conflicts such as livestock depredation (Treves and Karanth 2003; Woodroffe et al. 2005). A number of studies clearly demonstrate that spatial predation risk modelling can serve as a practical tool for guiding on-the-ground decision-making about where to implement preventative husbandry interventions and wild animal deterrents. Especially in situations where authorities routinely collect information on livestock mortalities as part of financial incentive or compensation programs, risk modelling can use existing data to offer additional insight into the spatiotemporal patterns and socio-ecological drivers of human–wild animal conflict.

Landuse change and its gradient can be estimated using satellite remote sensing techniques and GIS utilising multi-time datasets. GIS technology enables monitoring of wildlife and their habitats so that threats to biodiversity can be tracked and policies can be implemented to protect threatened areas. GIS technology is an effective tool for managing, analysing, and visualising wildlife data to target areas where interventional, management practices are needed and to monitor their effectiveness. GIS helps wildlife management professionals examine and envision the following: (a) habitat requirements and ranges, (b) population patches and linkages (c) disease levels within populations (d) progress of management activities, and (e) historical and present wildlife densities. The frequency of conflicts increases during the rainy season which also coincides with the harvest of major agricultural crops such as wheat, maize and paddy. The spatially-explicit predictive modeling approach is capable of linking a diverse spatial suite of environmental predictors with human-wildlife conflict (HWC) data. This approach also provides a powerful and flexible analytical framework for HWC studies by integrating and exploring the various bio-geo-environmental factors and can be used as a scaleable model for prediction in various regions. The results of such studies can be useful in the development and deployment of appropriate conflict mitigation strategies, such as guarding early morning system barriers and deterrents and also for planning alternative land use and livelihood strategies that will not attract HWC.

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COLLECTION, HANDINGLING, MAINTENANCE AND IDENTIFICATION OF RODENTS

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COLLECTION

Field rodents are being collected by using live traps like Sherman traps. Before putting in laboratory, it is essential to record it morpho-metric and reproductive status.

HANDLING

Animals trapped form fields by live traps (Sherman trap) are transferred to the animal cages made up of thick wire mess. For transferring the trapped rodents in to cages strong, dark, cloth bag measuring 60xcm to 75x30 cm may be used. Glass Jars with Bakelite cap (1000 ml capacity) may also be used to transfer the animals. The animal is normally confined to the end of the cage whenever, put the glass jar or the cloth bag on mouth of sliding door, Open the door slowly, disturb the animal by making sliding noise on upper side of the cage/ trap. The animal will come out and enters the jar/bag. If this whole procedure is carried out calmly, the rat will not get into stressed condition.

All rodents bite as natural response to fear, freshly collected wild rodents may be harboring unknown bacterial or viral diseases, precautions for the well being of the animals as well as personnel should be taken. Handing gloves will give protection. If necessary, to leave the animal by its tail, it should be held at the base and the Wight of animal quickly supported because some of species like, *Milardia meltada Golunda ellioti* and *Cremnomys cutchius* have scaly naked tail, which will shed the skin if handled carelessly.

ANESTHESIA

After removing from the traps, the morpho-mertric parameters like Body weight, Head and Body length (Hb), Hind foot, Tail length, length and ear pinna should be recorded, it’s reproductive status (adult, sub adult condition of testis (scrotal or abdominal), vagina (perforated or imperforated) should also be observed. For these studies, it is necessary to anesthesia the animals by soaking a cotton swab with ether. A mixture of ether and air would be a better anesthetic agent. When activities completely cease and seems unconscious, remove it from the jar and record the above-mentioned morph metric parameter.

HOLDING CAGE

Rodent should be caged individually in the rodent house and provide them food and water. On the basis of their ecological characteristics in the wild, the animal should be provided similar conditions in the laboratory also to make them feel comfortable. Some gerbils like *M. hurrianae*, *Gerbllus gleadwi*, and *G. nanus* take sand bath and prefer sand of micro habitat. So, it is advisable to provide sand bed in the cages. However, for tree mouse, *Vandeleuria oleracea* which resides on trees. It is better to provide rotating wheel in the cage. Bush rat, *Golunda ellioti* makes nest in natural habitat using grass clumps. If dried grasses are provided in the cage. It will help the bush rats maintain them comfortable in the cages. Similarly, *Mus platythrix* collects small pebbles around its burrow openings in its natural environment. Thus, putting small pebbles in the animal cage will provide a familiar condition.

FOOD

Rodent are basically seedivorous/ herbivorous but most of the desert dwellers change their diet according to the seasons. For example: seeds constitute the greater share of the food of gerbils during the month of Jan and Feb. By the end of the March, the percentage of the seeds in their diet decrease, while that of stems and rhizomes increases. During summer month, when sever conditions prevail, no single clump of grass is present on sand dunes, seeds in food of the desert gerbils decrease considerably and that of stems and rhizomes increases to 45 percent. However, invasions of locusts start and gerbils also start feeding on them and a small number of ants and beetles is also taken. Insects constitute 15 percent of their food during summer. Again, in the month of Oct Nov, and Dec. their percentage of the seed increases upto 30 to 60 percent and stems and rhizomes decreases to 10 percent. To accept an omnivorous diet make them ‘Fit’ to survive in harsh conditions of desert. This ability of rodents has led their worldwide distribution rodents. To know the best –preferred food of a a particular species studies on food preference should be carried out. It is found that bajra (*Pennisetum typhoides*) is highly preferred food for most of the species. It is advisable so acclimatize for further caught animal in captivity for a period of 3 weeks before using them for further experimental works/studies so tha t the animal gets time to recover for the stresses, if any.

BREEDING

Most of the species, particularly gerbils that are kept in cages oppose captive breeding. However, *B. bengalensis*, *Nesokia indica* breed successfully. However, gerbils can be bred satisfactorily in the animal house, with some degree of success depending on the suitability of the conditions like space. a nesting box with nesting material, proper food and water, green vegetables and the minimum human interference. In case of *M. hurrianae*, and *T. indica* cannibalism are very common. This behavior can be checked by providing sand bed and nesting material like hay and cotton etc. Postnatal mortality can also be reduced considerably to providing such conditions.

Some animals like *N. indica* and *B. bengalensis* mate satisfactorily in captivity. Both the mole rat species breed year around in natural habitat So, it is better to leave an adult male and female together throughout the breeding program rather than remove the male whenever the female becomes pregnant. Most of the gerbils are showing two breeding peaks i.e. February, March and July August. The gerbils pass through cold spell in December and January in a state torpidity. As soon as this torpidity is over, sexual activity increases and hence the peak births in February. The increased activity in July –August is attributed to the optimum and favorable conditions existing during rainy season in the desert.

This information to be recorded after the birth of young ones are:

- Weight of young one at birth
- Size of young one
- Colour of the body
- Time of the suckling after birth
- Morpho metric observations
- Post-natal development and behavior of young.
- Period of suckling / Location
- Parental care
- Cannibalism, if any
- Age of sexual maturity etc.

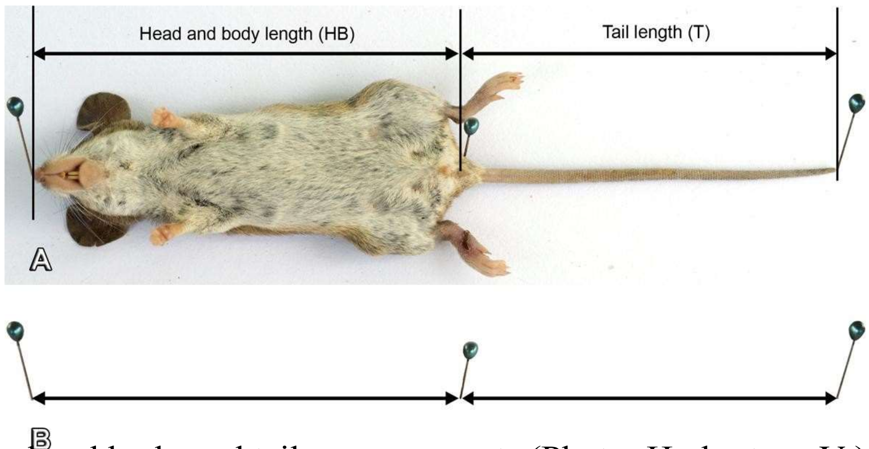
IDENTIFICATION OF RODENTS

(Vincent Herbreteau, Yannick Chaval, Jean-François Cosson and Serge Morand)

A. Morphometric measurements are necessary for a correct identification of the species.

1. Body weight: Measure the weight (in grams) of animal using a digital/spring balance as per availability and place of working (i.e field or laboratory).

2. Head and body (HB) length:



Head and body and tail measurements (Photo: Herbreteau V.)

Place the animal lying on its back, in a straight position, without stretching the body, mark the landmarks of the body such as tip of the nose and the anus. Then measure precisely the distances between the marked points with a ruler as shown in fig.

3. Tail

Place the animal lying on its back, with the tail in a straight position. Mark one point on the side of the anus and a second one on the tip of the tail. Do not include terminal hairs, if present, but measure their length separately (in the case of squirrels, etc.).

Verify that the tail has not been cut at its extremity: in such case, the tail looks like intact but its extremity is square (the tail length would be a little shorter and it may result in a wrong identification). If the tail is cut or damaged, indicate, "cut" when recording data, and add in brackets the length of the cut tail (it can be useful for identifying the species of the animal).

4. Hind-foot (or pes) length

Position the ruler and flatten the hind-foot on it and measure the distance between the back of the heel and the tip of the central toe, without including the claw.

Hind foot measurement not including claw (Photo: Herbreteau P.)

5. Ear

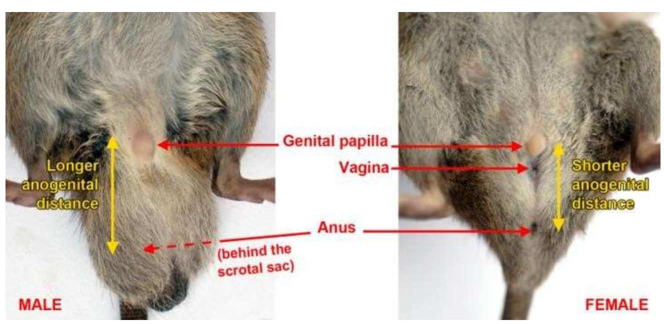
Introduce the ruler (with the extremity starting at "0") into the ear and measure the distance between the notch (at the base of the ear) and the extremity of the ear. Verify that the ear is not cut or damaged at the extremity.

Ear measurement (Photo: Herbreteau P.)

B. Sex determination

Male and female can be differentiated by observing their external reproductive organs:

1. Presence of scrotum covering testicles in adult males and of the vagina in females (Fig.). Nevertheless, juvenile males have their testes inside the body and can be confused with juvenile females. Differentiation can be done by observing the distance between the anus and the genitals, which is greater in males than in females. If the identification cannot be done using external morphological features, the internal reproductive organs should be observed at the end of the dissection.



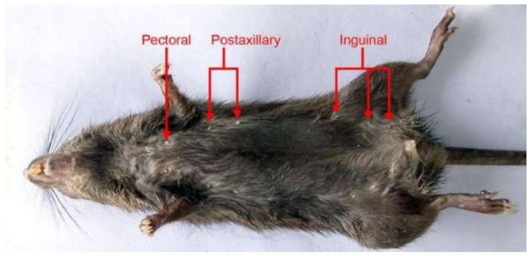
External comparison of male and female reproductive organs (Photo: Herbreteau V.)

1. Females

(a) Vagina: the vaginal opening is covered by a translucent skin in juvenile females. Record if the vagina is "not perforated" or "perforated".

(b) Teats: Record if teats are "barely visible" (hardly distinguished and enumerated) or "prominent".

(c) Mammary formula: It corresponds to three parts of the body, from the top to the bottom: pectoral + post-axillary + inguinal (Record the number of teats on left and right side of each position). If the female is pregnant, mention the number of embryos on each side (on dissection).



Position of teats (1+2+3) (Photo: Herbreteau, V)

2. Males

Indicate if the testicles are "inside" (i.e. abdominal = juvenile), or outside (i.e. scrotal or descended into the scrotal sac = adult).

C. Maturity determination and development stage

The determination of sexual maturity (immature/mature) and that of the development stage (juvenile/sub-adult/adult) are both necessary to understand the ecological traits of an animal as well as to interpret epidemiological results. Also, it can help to correctly identify an animal to the species level. In some case, juveniles could be misidentified with adults from another species. Figure 41 shows such difficulty with an adult Rattus exulans and a juvenile Rattus tanezumi, which look like similar in size and shape. However external observation can help to distinguish juveniles from adult individuals. Juveniles usually have a soft fur and their skull, ears and feet are larger (relative to their body size) than those of adults.

The observation of the sexual organs is highly informative to assess their sexual maturity:

1. Juveniles

Juvenile females: The vagina is not perforated and teats are barely visible.
Juvenile males: Testes are abdominal (inside the body cavity), the scrotal sac is not apparent.

2. Sexually mature individuals

Females: The vagina is perforated and teats are easily visible. Verify the presence of embryos or scars in the uterus.

Males: Testes are scrotal i.e., descended into the scrotal sac; seminal vesicles are well developed when the animal is sexually active. In rare cases, testicles can be inside the body even if the scrotum and the seminal vesicles are developed: note these observations in the data sheet

BIOACOUSTICS: A PROMISING TOOL FOR MANAGEMENT OF HIGHER VERTEBRATES

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Crop raiding by animals, in particular mammals like elephants, gaur, blackbuck, chinkara, wild boar, monkey, Hanuman langur, Nilgai etc has been widely reported from all over the country. Incidences of human casualties, livestock depredation and crop damage caused by wild animals e.g. elephant, tiger, lion, sloth bear, leopard, nilgai, deer, wild boar etc. are been widely reported from various parts of India. However, damage to properties and agriculture crops by most of the higher vertebrates is not well documented and is likely limited to isolated incidents where these animals cause damage while searching for food. In case of Wild boar and Nilgai, due to suppression of their natural habitats and food resources, these animals are forced to depend on the agricultural crops. In case of Rhesus monkey, in recent days most of the populations came out from their natural habitats and become commensal (Southwick and Siddiqi 1994). These commensal monkeys have started increasing in populations, due to availability of potential food resources and less predatory pressure. As populations expand into areas near residential areas, concerns arise from the potential for people to begin feeding monkeys which conditions the monkeys to associate people with food sources. This association can often lead to attacks on people and damage to property as monkeys search for food in residential areas. Most of the Rhesus monkey populations are becoming semi commensal and frequently raiding on the agricultural crops and cause enormous damage to the agriculture and some of them are found sitting along the road sides and begging food from the vehiclers, and in some situation’s monkeys have started attacking on the human beings and steeling food from them.

To date there has been comparatively very little systematic research carried out to investigate patterns of crop raiding activity by wild animals, its potential impact on farmers' food and household economic security and ways and means to manage them. The majority of the research that exist at present has focused on the issues related to crop damage by rodents, however information on higher vertebrates such as primates and ungulates often cited as troublesome 'pests' in agricultural areas is scant and scattered.

In recent years problems of higher vertebrates in agriculture is on rise in many regions and many times severe crop damage is reported. The major reason for vertebrate problems in agriculture is in order to increase the production/productivity for growing population, a large area is being brought under cultivation by replacing natural ecosystems to human managed systems resulting into fragmentation of habitats for wild animals, which force them to inhabit croplands causing severe damage to standing crops. Degradation of natural habitats, reduced predatory pressure and regular availability of nutrient rich food (crops) round the year are likely to provide greater resilience and adoptability of wild animals which allows them to live successfully close to agricultural landscape and human habitation.

Damage caused by wild boars to agriculture has become a matter of serious concern and needs to be managed effectively. Farmers across the nation are suffering badly due to their menace. Since these animals are protected under Wildlife protection Act, their management through non-lethal approach is the pre requisite to minimize the crop losses as well as man animal conflict.

Keeping in view of the situation, ICAR under 12th five-year plan-initiated research on management of higher vertebrates in agriculture to mitigate the damage pattern by the wild animals under this activity bioacoustics a new technology was developed by AINP on VPM to deter wild boar, Nilgai and monkeys from agricultural landscape

The bioacoustic technology uses only natural sounds of predators, distress and alarm calls of target and closely related species of target animals. The calls are broadcast in a field by using an electronic platform with sound drives. Bioacoustics tries to convey the message 'this area is dangerous' to the target animals in their own language. On hearing the sounds, the target animals start avoiding the area, thus saving the crop from being damaged. The sounds are natural and safe on humans, birds and animals.

Alarm call: Alarm call is a ritualized means of communicating a danger or threat among the members of an animal group. Many animals that give alarm calls when they see predators. Such calls were captured in field and used.

Distress call: Distress calls are the calls produced from the prey species while it is captured by the predator or when it is being captured and tortured. The calls will alert the remaining animals present in the location by intimating the threat.

Predatory call: Predators are wild animals that hunt, or prey on, other animals. The calls produced from the predators while hunting or before hunting is called predatory calls. This will alert the other animals present in the ecosystem by showing the danger sign. These calls were subjected to sonogram analysis and purified all the other unwanted calls. The purified calls were placed one after the other and developed call sequences.

The equipment produces fixed volume of 110dB at source covering an area of 4-5 acres when ambient noise level is around 42 dB. At 37 dB of ambient noise, the equipment can cover up to 19 acres. The equipment should be ideally installed when the animal damage is beginning. Bioacoustics is 92% effective in dispersing wild boar from the cropped area.

There are two models of equipments:

(a) **AC version:** Works on commercial electricity, and battery. Comes with device with inbuilt battery and a speaker.

(b) **SP version:** Works on commercial electricity, battery and solar power. Comes with device with inbuilt lithium ion battery solar panel, frame for solar panel, speaker fixing frames for device and speaker.

Specifications of the Bioacoustic equipment

Weight: AC version - 10 kg; SP version - 10 to 18 kg
Material: Powder coated MS Cabinet
Frequency range: 80 Hz to 19600 Hz
Battery: 12v, 9 or 17 Ah
Battery backup: 14-20 hrs
Operation modes: Day, Night, 24-hr
Mode switch over: Automatic
Solar panel: 20W
Weather suitability: Suitable for outdoor use under rainy conditions. Lightening resistant
Operating temperature: -250 C to + 480 C
Memory capacity: 4GB expandable to 8GB.
Plug and Play: The device can be plugged to an electrical socket (AC versions) for direct playing.
Sound level: 110dB using alpha weighting at source.
Height of installation: 15 to 30 cm above the canopy of the crop or 1 to 1.5 m is minimum installation height
Type of crops: Can be used for all types of crops where wild boar, Nilgai and Monkeys is a menace.

SUCCESS STORIES

Bioacoustical equipment was installed in Telangana states at different farmer's fields, Agricultural Research stations, plagued by wild boar menace. The technology was tested in many crops including short and long duration one viz., Sugarcane, Maize, Groundnut, Sorghum, Rice, Vegetables, and Banana.

1. Farmer Shri. N. Dhasaratham

Village: D. Dharmaram, Medak, Telangana State
Grows: Maize and paddy

Damage by wild boar: 30% before installation

Before installation of the bioacoustic equipment Farmer Shri N. Dhasaratham of D. Dharmaram had wild boar menace in his two-acre maize field and one acres of maize field. In one-night, wild boar damaged almost 30% of his maize field.

Bioacoustic equipment was installed at his field on 22-Aug-2018

My field is now completely protected from wild boar damage. After installing this equipment, even my neighbours are also reaping the benefit. Wild boars are not coming to our area for the past two months. We expect to harvest a good crop' - N. Dhasaratham.

'

Installation of bioacoustic equipment at D. Dharmaram village

2. Farmer Shri. Bal Reddy

Village: Raghavpur, Rangareddy, Telangana State
Grows: Maize

Damage by wild boar: 15% before installation

Bioacoustics operating since: Two months

Farmer Shri Bal Reddy of Raghavpur village kept a constant night guard to protect his maize, but despite it, the wild boars damaged the field. He was unable to invest on other traditional methods of wild boar management except keeping a night vigil.

Bioacoustic equipment was installed at his field on 26-Aug-2015

Mr Bal Reddy saus “'I am happy about bioacoustics equipment. It has literally freed me from the burden of keeping a constant vigil in the night. Now I don't have to patrol my crops every night”

Installation of bioacoustic equipment at Raghavpur village

Trials conducted in Telangana

With the help of State Govt Agricultural department conducted trials in 148 locations of Medak and Rangareddy district through Agricultural Technology Management Agency (ATMA), DAATT centres and SAU. Maize, sorghum and rice cropping systems with rampant wild boar menace were targeted. The increase in yield from control plots were 50% to 74%. The farmers observed that bioacoustic protected fields were completely protected from wild boar menace with no crop damage.

RODENT MANAGEMENT IN COMMENSAL SITES AND STORAGE

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Next to man, the rodents are considered as most successful and abundant mammals on earth and competitively share human habitats and food for their successful survival. Commensal rodents, mainly the rats and mice, are intimately associated with various human activities, live in human houses, eat and contaminate our food and also transmit several diseases. It has been estimated worldwide that there is one rat for every human being. These tiny creatures have even been referred in some of the oldest Indian scriptures the "Atharva Veda" and "Bhagwat Purana" (3000-200 BC). In Atharva Veda, it is mentioned that, "O Ashwin kill the burrowing rodents which devastate our food grains. Cut their heads, break their necks, plug their mouth so that they can never destroy our food" (Anon, 1959, British Encyclopedia). Bhagwat Purana (10th to 11th century) recognizes the potential of rats in spreading deadly diseases (probably plague) when it warns "desert your dwellings as soon as dead rats are seen in the house".

Rats consume about 25 g of food per day and mice eat approximately 3–4 g per day. They contaminate a lot of the stored produce with urine, feces, hair, and pathogenic agents. Infested batches often have to be declared unfit for human consumption. As rodents mainly feed on the embryo, they cause particular damage to the nutritional value and germination ability of seeds.

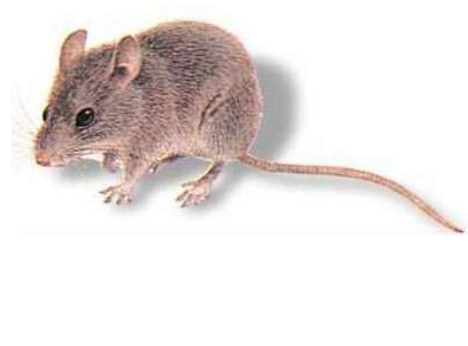
RODENTS OF ECONOMIC IMPORTANCE IN STORAGE

The principal rodents, those most common and likely to attack stored products, belong to the following species:

- Black rat, also called roof rat (*Rattus rattus*)
- Brown or Norway rat, also called sewer rat (*Rattus norvegicus*)
- Mouse (*Mus musculus*)

1. The house mouse, *Mus musculus* (Family Muridae): The house mouse, Mus musculus is a tiny animal weighing 15-20g. Tail is naked and longer than body length. Dorsally, the colour varies from brown to light brown with belly being whitish to light gray.

Distribution: Cosmopolitan in distribution. Being commensal it is a nuisance to many items in addition to spilling and spoiling a lot more than eating. In fields it is known to damage sugarcane, groundnut etc. By cutting wires it causes power failures and



computer shut downs, which are financially disastrous by affecting production.
Habitat and Habits: Commensal, nesting in rafts, crevices in walls, amidst staked undisturbed bags of food grains in godowns, table draws; often lives in fields digging burrows. Nocturnal.
Breeding: The commensal, Mus musculus also breeds round the year, however in Rajasthan it is least during summers and extreme winters, thus recording a bimodal pattern of breeding season. Litter size varies between 1-8.

2. The House rat, *Rattus rattus* (Family Muridae, Subfamily, Murinae): It is a medium sized rat weighing 100-150g. R. rattus also called roof rat, black rat and ship rat and is the most abundant and widely distributed rodent species in India as well as the world. Rattus rattus is characterised by long tail, slender body and pointed snout as well as the belly. The dorsal fur is mostly blackish in commensal forms.

Distribution: All over the world. In Rajasthan also it is the most common rodent species sharing with human inhabitations in houses, stores, godowns etc.
Habit & Habitat: Mostly commensal living in houses, godowns, stores, poultry farms, crop fields, adjacent to villages, plantation crops, especially coconut, open country, forests and in the hills. It is nocturnal and colonial.
Breeding: House rats breed throughout the year, reportedly with two peaks of reproduction viz. March-April and August-September.

3. The Norway rat, *Rattus norvegicus* (Family Muridae): R. norvegicus is primarily a temperate zone rodent pest–both commensal and field pest. Its distribution in India is limited to harbour cities of Mumbai and Kolkotta. It is nocturnal and commensal in India and weighs 250-350g. Body brownish dorsally and ventrum whitish or off white. Although inhabits sewers elsewhere, in Kolkotta and Mumbai it digs burrows in godowns and is a warehouse pest.

Rattus norvegicus

MANAGEMENT

Rodent management, particularly in commensal sites (viz., houses, hospitals, stores and godowns etc.) can be made through three major integrated approaches of rodent control viz., environmental techniques, use of mechanical devices and chemical toxicants are discussed below.

1. Environmental methods

Proper storage of feed, prevention of spillage and timely removal of garbage and sewage, waste material, unserviceable equipments and weeds in the surroundings, reduce the resting, hiding and nesting sites for rodents. Periodic cleaning in and outside premises reduce invasion of rodents. Similarly keeping the rodents away that is excluding them through physical barriers at their entry points is the best approach. The basic principle is to find out the entry points of rodents into the premises and these should be sealed or blocked with proper material. The possible route of entry of rodents and proofing techniques are detailed below:

Route of entry	Rodent proofing techniques
Drain and sewer holes: Rodents may enter premises through uncovered drain, holes, sewers and gutters.	Fixing tightly fitted perforated metal sheet covers on drain holes and by keeping sewer and gutters properly covered.
Water and drain pipes and electric cables : Rats climb along pipes and wall and also move along cables.	Installing guards on outside pipes and by sealing space around them and cables.
Windows and ventilators: Open and damaged windows and ventilators allow entry of rodents. Roof rats climb poles, pillars, and can enter ventilators.	Fixing permanent screen of wire mesh (24 gauge expanded metal) with holes less than 6 mm size. Structures near to windows and ventilators on which the rats may climb need to be removed.
Doors: Rodents enter through the under-door space, holes made by gnawing, damaged and open doors.	Proper fitting of doors in their sills and jambs, fixing of 20 gauge galvanized iron sheet on lower border up to 24 cm, door sweeps and door closers.
Burrows: Wild rodents dig burrows in foundation and floor through which they keep moving to and from the premises and wild habitat.	Using concrete and mortar in foundation, floor and perimeter strip around the premises.
Cracks and joints: The commensal rodents use cracks and joints for nesting and hiding.	Sealing the cracks with concrete and fixing metal sheet on joints reduce their activities.

2. Mechanical methods

Mechanical means of rodent control involves removal of rodents with traps, such as multiple catch 'wonder traps' and single catch 'Sherman traps' and kill type traps viz., 'snap traps' and 'glue traps'. Regular trapping is the safest, convenient and economic method for rodent control where rodenticides are considered too risky. All the live-trapped rodents should be killed by dipping the trapped rodents in water.

3. Chemical Methods

It involves use of poison. Two types of rodenticides viz., acute e.g. zinc phosphide and chronic anticoagulants e.g. Bromadiolone is used to control rats. These rodenticides are used in form of baits.

(a) Bait formulation

(i) Zinc phosphide (2.0%): Being an acute poison, it is highly toxic not only to rodents but to wide range of animals including man. Therefore, it is not advisable to use it in and around hospital premises. Most of the rodents consuming the lethal dose die within 2-12 hours. Poison baiting with this rodenticide requires pre-baiting with plain bait. Moreover, it should not be used continuously for more than 1-2 days. For its bait preparation we require:

(i)	Pearl millet/sorghum/cracked wheat	:	960g
(ii)	Vegetable oil (ground nut /sesame /mustard)	:	20g
(iii)	Zinc phosphide	:	20g

These ingredients are mixed thoroughly in a container with a stick (no household utensil be used for this purpose). The baits should be prepared fresh each time when required.

(ii) Bromadiolone (0.005%): These are anticoagulant rodent poisons and the target rats die after 3-10 days after consuming the poison bait. Bromadiolone is available as ready to use wax cake (0.005%) and bait concentrate (0.25%). Fresh baits of this poison at desired dosage can be prepared by mixing the following ingredients:

(i)	Pearl millet/ sorghum/Cracked wheat	:	960g
(ii)	Vegetable oil (Arachis/ sesame/ sunflower)	:	20g
(iii)	Bromadiolone bait Concentrate (0.25%)	:	20g

(b) Bait Application

(i) Open fields: Zinc phosphide bait most not should be used in the premises, however, it may be used in the open fields around the premises at 2.0-2.5% w/w concentration in pearl millet baits with utmost care. Preference should be given to safer rodenticides viz., bromadiolone. In open fields, the poison bait should be rolled deep inside the live burrows (@ 10-20 gm/burrow) and dead rodents, if noticed, on subsequent days must be disposed off by burying these deep in soil.

(ii) Inside and around premises: Bromadiolone baits should be placed in bait stations @ 25-50 gm/station in the rodent runways. The anticoagulant baits may be replenished daily for 3-4 days and afterwards all the leftover/unused baits must be disposed off.

PRECAUTIONS

(i) No eating, drinking or smoking should take place when live or dead rodents or poison baits are handled.

(ii) All cuts and abrasions on the hands and arms should be covered before starting the work.

(iii) Any rodent bites should be reported and sought medical advice.

(iv) Poison baits should be prepared in well ventilated room and care should be taken not to breath in or absorb any poison.

(v) After poison bait preparation and field application, hands should be washed with soap properly.

(vi) All poisons (pure chemicals, baits etc.) should be clearly labeled 'POISON' and held in a locked almirah and should be away from the reach of children.

(vii) The poison bait should not be touched by bare hands. Any broad leaf or spoon or gloves, if available, should be used.

(viii) When poison baits are laid, the residents/owner of the area should be cautioned about the treatment so that children, livestock and pets can be kept away for a day or two.

(ix) Poison bait should not be laid where the excess bait cannot be picked up in order to prevent any later danger. A record should be kept of the number and location of baiting points.

(x) While placing the baits in the burrow, the poison bait should be rolled deep in the burrows to protect birds, livestock and other non-target species.

(xi) After the control operations, the left-over baits, should be picked up and dead rodents be collected and buried deep in the soil.

Identification of some rodent pest species

Body not covered with quills or spines

Body covered with quills or spines

Tail normal without any thick & full cover of long hair; most of the species fossorial in habit

Tail thick and fully covered with long hair; arboreal in habit

Squirrels

Five stripes on dorsal side
Funambulus pennanti

Three stripes on dorsal side

1. *Funambulus tristriatus* (Western Ghats)
2. *Funambulus palmarum* (Rest of peninsular India)

Tail normal without ending in hairy tuft

Tail long ending in hairy tuft

Soles naked not covered with hair, Peninsular India excluding deserts.
Indian gerbil or antelope rat; *Tatera indica*

Soles partially covered with hair, lives in desert ecosystem. Indian desert Gerbil; *Meriones hurrianae*

Tail normal without ending in hairy tuft

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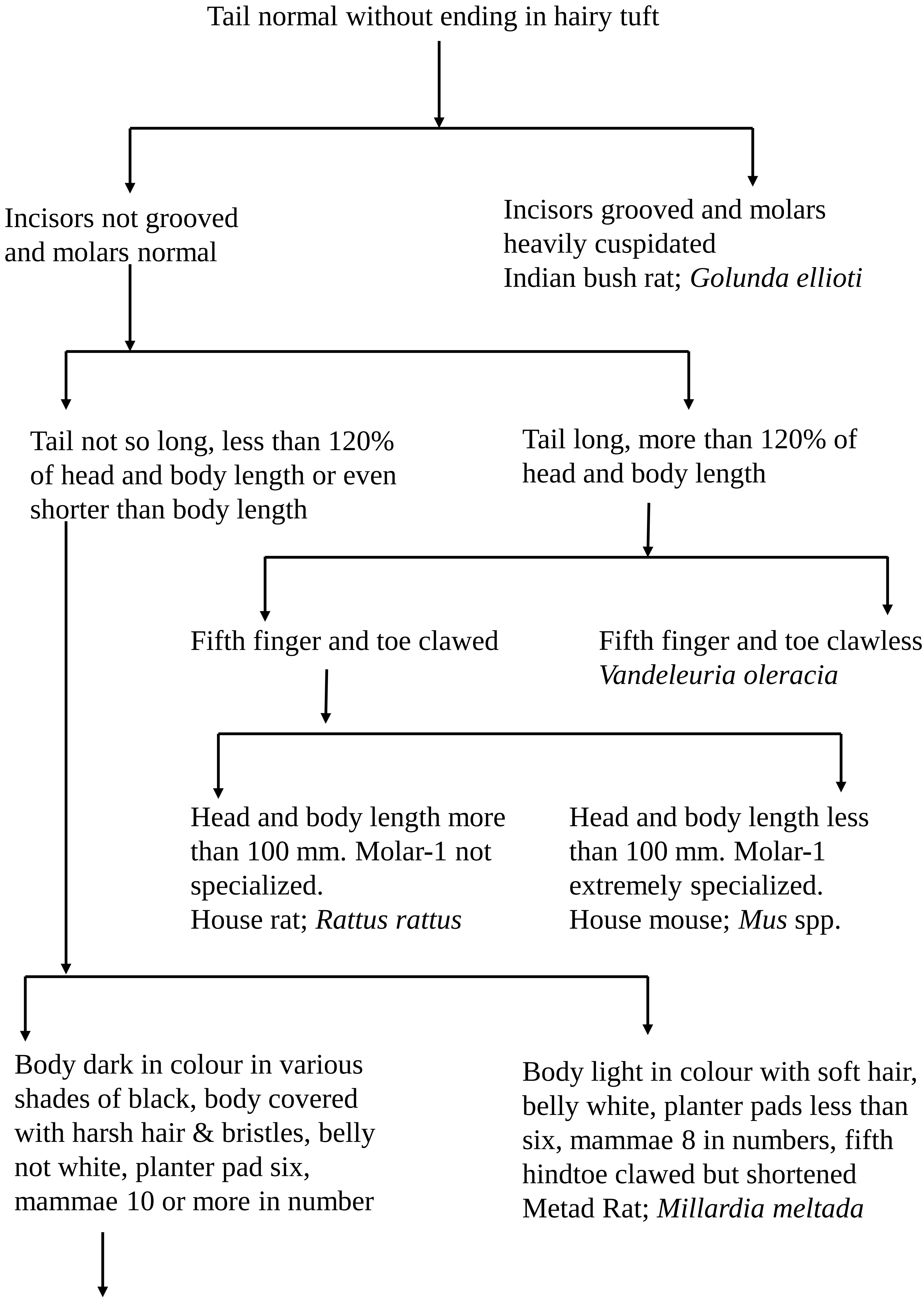

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Body dark in colour

Tail not so short, more than 2/3rd of Head and Body length

Tail short, less than 2/3rd of Head and Body length
Short tailed mole rat; *Nesokia indica*

Head + body length in general, less than 220 mm, snout triangular, occipitonasal length less than 45mm and zygomatic with more than 57% of occipitonasal length, occipitonasal length always less than condylobasal length
Small sized bandicoot rat; *Bandicota bengalensis*

Head+ body length in adult specimens, in range of 210 mm to 300 mm, snout rat like and not triangular, occipitonasal length more than 45 mm and zygomatic width less than 57% of occipitonasal length. Occipitonasal length always less than condylobasal length.
Medium sized bandicoot rat

1. *Bandicota indica indica (Pen. India)*
2. *Bandicota indica malabarica (west. ghats)*

Head + body length in adult specimen in the range of 270 to 370 mm, snout more or less triangular, occipitonasal length more than 45 mm. Zygomatic width less than 57% of occipitonasal length equals to more than condylobasal length
Large bandicoot rat; Bandicota maxima

Rattus species

Under part not white

Under part white
White bellied rat*; Rattus rattus wroughtoni*

Tail always long, more than 120 % of head + body length

Tail shortened, sometimes less than Head + Body length
Norway rat; *Rattus norvegicus*

Rats with dorsum rofous in colour, belly hair dull with rufous tinge.
Common House or Roof rat;
Rattus rattus rufescens

Uniform black coloured rat
European Black rat;
Rattus rattus rattus

Mus species

Small sized mouse, ventral side white, upper incisors short, tail bicoloured, lives in crops, fields, forest fringes etc.
Common Indian field mouse;
Mus booduga

Small sized mouse, underparts may or may not be white, incisors normal, lives in houses.
Common House mouse;
Mus musculus

Annexure-II

PROFORMA FOR THE SURVEILLANCE OF RODENT PESTS

Name of the District and Block: Name of the Village:

Name of the Official: Name of the Crop Variety:

Date of Observation: Stage of Crop:

Item	**Plot 1**	**Plot 2**
No. of live burrows (in 10 areas)		
Rate of infestation (No. of live burrows per hectare)		
Level of incidence: Less/Moderate/Severe		
Damage incidence:		
(Method: Diagonal)		
Total No. of Tillers/plants observed:		
No. of damaged tillers/plants:		
Incidence of damage (%)		

Remarks, if any:

Annexure-III

DATA SHEET FOR RECORDING MORPHOMETRICS AND BREEDING BIOLOGY OF COLLECTED RODENTS

Locality;…………..**Habitat:-**Sandy/Gravel/Rocky/commensal/crops/forests

Date:…………. …. **Animal No:**. …………………

Adult: ……………… **Subadult:**…………….. **Juvenile:**………………

Body wt:…………**HB:**………**T:**……………**HF:**…………….**E:**………

Testes:……….. Scrotal/Abdominal

Vagina: Perforated/ imperforate

Non-porous/pregnant/ Lactating/ Non-Lactating

No. Teats RT……………… LT…………….

Condition of teats: Regressed/ swollen/ suckled

Abnormality/Remarks……. ………………………….. ………………………..