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Agriculture is very important to the economy of Pakistan, and economic losses are high due to depredation by vertebrate pests on crops. This training manual on vertebrate pest management was compiled from a series of lectures given at several annual training courses at the Training Institute, National Agricultural Research Centre, Islamabad. The Government of Pakistan has launched programs to research and develop safe, effective, and economical vertebrate pest control methods that are suitable and practical in the farming systems of Pakistan. This manual provides information for those dealing with vertebrate pests, not only in Pakistan but also for adjacent countries in the South Asian region.

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VERTEBRATE PEST MANAGEMENT

A GOP/USAID/DWRC
Vertebrate Pest Control Project
National Agricultural Research Centre
Pakistan Agricultural Research Council
Islamabad - PAKISTAN

A Training Manual

on

Vertebrate Pest Management

Editors :

Joe E Brooks
Ejaz Ahmad
Iftikhar Hussain
Shahid Munir
A. Aziz Khan

A GOP/USAID/DWRC
Vertebrate Pest Control Project
National Agricultural Research Centre
Pakistan Agricultural Research Council
Islamabad.

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3. Lagomorphs 4. Wild boar 5. Birds

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FOREWORD

The agriculture sector plays an important role in the economy of Pakistan. The prosperity of the people of Pakistan critically depends on the efficient utilization of agricultural resources and the performance of this sector as a whole. The R&D activities in the sector are oriented to develop and disseminate improved production technologies to enhance agricultural productivity per unit area in the country.

Maximum benefits from the production technologies cannot be realized unless the crops and crop products are protected from pests, weeds and diseases. Historically, pest management in most of the Asian countries remained limited to insects and disease control while little attention was paid to vertebrate pests. In Pakistan, the vertebrate pests depredations on agricultural crops are serious and economic losses run into billions of rupees annually. Failure to protect crops from the ravages of vertebrate pests means that the new developments in agricultural technology for enhancing yields may not be utilized to their full potential. Also, the costly agricultural inputs are wasted as the vertebrate pests cause both pre- and post-harvest damage.

Recognizing the magnitude and importance of the problem, the Government of Pakistan launched two national programmes to undertake research on various aspects of vertebrate pests and to develop safe, effective and economical control methods which are suitable and practical in the farming systems of Pakistan. These programmes were executed with the collaboration of FAO/UNDP and USAID (FSM Project). As a result of the activities of these programmes, a body of knowledge on vertebrate pest management was developed which has been presented in this training manual. I hope that the consolidated information contained in this publication will prove highly valuable for researchers, subject specialists, extension workers and graduate students.

The efforts made by the editorial committee in compiling this publication are appreciated.

(Dr. C. M. Anwar Khan)
Chairman
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Islamabad

PREFACE

This training manual on Vertebrate Pest Management grew out of a series of lectures given at several annual training courses on vertebrate pest management at the Training Institute, National Agricultural Research Centre, Islamabad. Originally, they were simply compiled into a collection of lecture notes but, as the need for a manual was recognized, each author was asked to supply a more formal and complete outline. The lectures were then edited, rewritten and finally prepared as the present manual.

The material is divided into 36 chapters. Each deals with a specific aspect of vertebrate pest management. The first part of the manual covers the basic principles of vertebrate pest management. Rodent pests are dealt with in detail. Then follows a section on minor lagomorph pests: Afghan pika and desert hare. Four chapters cover Pakistan's most formidable vertebrate pest, the wild boar. The manual ends with five chapters on pest birds.

While the material has been prepared from the view point of problems in Pakistan, much of it is of general application and the manual should prove useful to workers in adjacent countries in the South Asian region.

To keep the material relatively simple, no references to the background scientific literature have been included. This may be regretted by some but was necessary to keep the material from becoming too cumbersome. Several comprehensive bibliographic reviews on major vertebrate pests of Pakistan are now available to help cover this need. Others are planned for the future.

We hope this training manual will create awareness of the importance of vertebrate pests in the Pakistan agro-ecosystem. It brings knowledge into areas where there was none or was available only in scattered articles. The publication of this manual should help those who need this knowledge.

The editors and authors wish to express their appreciation to those whose comments were used in shaping the materials for training. To all who labored hard on getting this manual ready for publication go our heartfelt thanks.

Permission to reproduce illustrations of several rodent species and their distribution maps from T.J. Roberts' *The Mammals of Pakistan* was kindly granted by the author and the publisher, Charles Knight Publishers, Croydon, England. This permission is greatfully appreciated.

We express our kind appreciation to the MART project staff for their assistance in utilizing the laser printer. Special thanks go to Mr. Khalil Ahmad, Scientific Photographer, SIU, NARC, Islamabad for his help in the preparation of illustrations in this manual.

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Editors

A REVIEW OF VERTEBRATE PEST PROBLEMS IN PAKISTAN AND THEIR IMPACT ON AGRICULTURAL ECONOMY

By Mian Mohammad Shafi

A. Introduction

No country is free from the depredations of vertebrate pests, especially by rodents, which in many cases cause severe economic losses resulting in malnutrition and even famine. Pakistan, having different climatic zones and with complex cropping patterns and practices, also suffers economic losses due to rodents, birds, wild boars, porcupines, and pikas, etc. Standing cereal crops and stored commodities are affected by rodent and bird pests. In some cases vertebrate pest damages have become limiting factors in the introduction of new crops, such as sunflower, which is seriously damaged by parakeets. This growing concern about the extensive damage caused to crops in fields and storages by vertebrate pests led the GOP to establish the Vertebrate Pest Control Laboratory (VPCL) in 1971 with the assistance of UNDP/FAO with the following research and development objectives:

- Identify the major vertebrate pest problems in different agroecosystems.
- Assess crop and food storage losses from vertebrate pests.
- Develop safe, effective and economical control methods through testing new products which are suitable and practical for farmers.
- Test rodenticides and avicides both under laboratory and field conditions so as to help the concerned agencies in regulating their use.
- Demonstrate vertebrate pest control techniques at farm level through pilot control programmes.
- Investigate rodent-borne diseases hazardous to humans and livestock.
- Transfer knowledge to the farming community through the Provincial Agricultural Extension Services by holding master trainer courses, seminars and producing a wide range of advisory bulletins, leaflets and pamphlets.

B. Identification of Problems

In Pakistan, there are 43 different kinds of rodents, the majority being rats and mice, but included are porcupines, giant flying squirrels, and some very exotic looking desert gerbils. Although fifteen species are regarded as pests, only five are of major importance which cause damage to major crops. Of great importance is the fact that the two major groups of rodents are represented among these five; those that live in desert and those that live in moist areas.

In ricefields, the lesser bandicoot rat, *Bandicota bengalensis*, is the major pest in the southern part of Sind and in major crop-growing areas of Punjab. *Millardia meltada, Nesokia indica* and *Mus* sp. are secondary pests of ricefields. In the sugarcane crop, *M. meltada* and *N. indica* are most abundant and cause damage to standing canes and their roots, respectively. In irrigated wheat fields, *B. bengalensis* and *M. meltada* are the primary pests in central Punjab and northern Sind, respectively. In rainfed areas, the wheat crop is damaged by sand rats or jirds (*Meriones* spp.) and bandicoot rat.

The porcupine, *Hystrix indica*, is a serious pest in forest plantations, root and vegetable crops, orchards, maize fields, and can cause breaches in canals, resulting in loss of irrigation water and property. Two other important vertebrate pests which are of economic importance are the pika, *Ochotona rufescens*, and the Murree vole, *Hyperacrius wynnei*. Both species cause damage to apple orchards, potatoes and forest nurseries in high mountain valleys of Ziarat (Baluchistan), Murree Hills and in much of Hazara Division mountains. They debark apple trees above and below ground level.

A major problem, widespread in Pakistan, is the wild boar, *Sus scrofa*, which does severe damage to crops and forests and is found in riverine areas, swamps, forests and irrigated lands. Sugarcane, maize, groundnuts and forest nurseries are severely damaged, in addition to minor damage to many other crops.

Among the many granivorous and frugivorous birds, only two are of major importance. The house sparrow, *Passer domesticus*, causes damage to cereal crops, although its role as a beneficial bird has yet to be determined. It also causes damage to bagged cereals in storages. The other bird pest species is the rose- ringed parakeet, *Psittacula krameri*, which does severe damage to maize, sunflower, citrus and minor damage to some grain crops. It has been observed recently, that house crows, *Corvus splendens*, pull out seedlings of wheat and pluck pods of groundnut.

In the post-harvest management systems, three rodent species; *Rattus rattus, Mus musculus* and *Tatera indica*, infest grain storages throughout the country. The Norway rat, *R. norvegicus*, a usual pest of grain storage, is found only in port areas in Pakistan.

C. Economic Losses

The results of extensive countrywide crop damage surveys conducted by the Vertebrate Pest Control Laboratory and repeated over two or more seasons are summarized in Table 1 and 2. Damage estimate techniques have been developed and improved to evaluate losses from rodents and birds to standing rice, wheat, sugarcane, sunflower, maize and citrus.

Field rats destroy as much as Rs. 193 million of rice crop in a bad year while losses to wheat are about Rs. 472 million. Sugarcane and groundnut crops are also severely damaged by rats and wild boar and economic losses are estimated at Rs. 534 million. Bird pests cause annual losses of over Rs. 500 million to wheat, maize, millets, sunflower and fruits. Pika, voles and porcupines cause Rs. 55 million damage to apple orchards and forest plantations. Altogether, it has been estimated that vertebrate pests cause economic losses (pre-harvest), directly or indirectly to the tune of Rs. 1893.00 million annually based on 1984-85 production statistics of crops.

Field studies by the VPCL showed that in the larger government-owned grain stores the losses from rodents altogether of economic importance, were overall of much less magnitude than pre-harvest losses in the field and post-harvest losses at farm/ village level. There are losses of about 1% in government owned storages and range from 5 to 10% at market and farm/village level.

D. Development and Evaluation of Management Techniques

Applied research trials have been conducted in all crops, orchards, forest and coconut plantations and grain storages to develop and evaluate different materials and methods to reduce vertebrate pest damage. A brief description of the work done by VPCL on these aspects is as follows:

1. Field Crops

In paddy, pilot trials using several rodenticides and baiting methods were conducted in Sind and Punjab. Twenty to 30% higher yields were obtained from the treated fields as compared to the untreated ones. In all these field studies 20- to 50-fold returns were obtained on the costs. In sugarcane

trials, mostly conducted in lower Sind areas, acute and chronic poison baits decreased the rodent population by 70 to 97% and a 1 to 8 cost/ benefit ratio was obtained. Control trials conducted in wheat fields in Punjab and Sind, using second generation anticoagulants and recently developed acute poisons, obtained 38% higher wheat yields.

Table 1: Estimates of Crop Losses Due to Vertebrate Pests in Pakistan

S.No.	Crop	Pest	Pre-Harvest (%)	Annual Losses* (Million Rupees)
1.	Wheat (irrigated & barani)	Rats Birds	2 - 9 2 -11	472.00 460.00
2.	Rice	Rats	3 - 8	193.00
3.	Sugarcane	Rats & Wild Boar	2.5 - 9	513.00
4.	Groundnut	Rats & Wild Boar	5 -10	21.00
5.	Maize	Birds & Wild Boar	5 -10	147.00
6.	Sunflower	Parakeet	14 -16	2.00
7.	Deciduous Fruits	Parakeet, Vole, Pika	5 - 6	25.00
8.	Citrus	Parakeet	12	30.00
9.	Forest Plantations	Porcupine	20 or More	30.00
			Grand Total	Rs. 1893.00

* Based on 1984-85 Government Support Prices.

2. Forests and Orchards

Various poison baits e.g. sodium monofluoroacetate (1080) strychnine and fumigants (Detia, Phostoxin & Cymag) were evaluated against porcupines in forest plantations and along the banks of big irrigation canals. All were highly effective but baiting may expose non-target species, hence utmost care is required in their use. A newly developed pyrotechnic device, which on ignition releases carbon monoxide, reduced the porcupine population by 80 to 90%.

Bait materials and techniques have been developed against pikas and voles. Against pikas, baiting using anticoagulants and acute poisons were highly successful in apple orchards. A sticky paint, "OSTICO", and a similar compound developed by VPCL gave 100% control against pikas and voles. Other control techniques using physical methods and habitat manipulation are still to be evaluated and preliminary results are highly encouraging.

Table 2: Estimates of Post-Harvest Losses in Grain Storages Due to Rodents

S.No.	Type of Store	Crop	Average Storage (mt)	Loss (%)	Total Losses (mt)	Annual* Losses (Million Rupees)
1.	Village and primary grain market level	Wheat	500,000	5	25,000	45.69
		Rice	800,000	5	40,000	120.16
2.	Public sector storages	Wheat	3,907,000	1	39,070	79.41
		Rice	5,292,000	1	52,920	169.56
			Total		156,990	414.82

* Based on 1984-85 Government Support Prices.

3. Wild Boar

Initial trials against wild boar, using zinc phosphide, endrin and 1080, conducted by VPCL indicated poor acceptance of zinc phosphide but endrin and 1080 were taken if mixed with molasses. Trials conducted by the scientists of the University of Agriculture, Faisalabad showed that high mortality of wild boar can be achieved with Temik by using different kinds of bait materials. Later trials conducted by VPCL, where prebaiting was done with plain bait followed with 1080 at 0.03% in baits, were successful in killing 80 to 90% of the boars. Trapping, as used in Australia and New Zealand, has not been evaluated in Pakistan. Economic exploitation of the wild boar population might be an effective method of controlling this pest but would be difficult in a Muslim country.

4. Bird Pest Control

Birds are difficult to control because of their behaviour and feeding habits. Field studies have given erratic results when using bird repellent chemicals against parakeets and house sparrows. However, in one case, the maize crop was protected from parakeet damage when methiocarb mixed with water and a sticker was used at the rate of 2-3 kg/ha. Laboratory evaluation of a distress-producing chemical, 4-aminopyridine, indicated that both parakeets and house-sparrows are susceptible to this material at normally recommended field concentrations.

5. Prevention of Losses in Grain Stores

Field studies conducted by VPCL, mostly in Karachi, indicated that liquid baits of warfarin are highly effective in small stores as compared to open shed type stores. In private sector grain storages, the trials were highly successful when tracking dusts of zinc phosphide (5% & 10%), pyriminyl (10%) and coumatetralyl (0.0375%) were used in bait security boxes. Use of ultrasounds or other non-chemical methods have not been tried yet.

GENERAL PRINCIPLES OF VERTEBRATE PEST MANAGEMENT

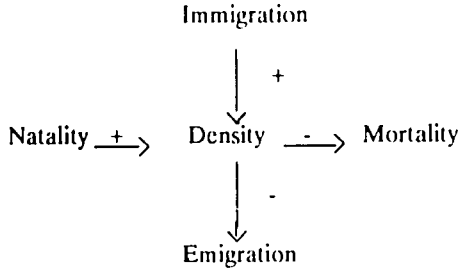
By Mirza Azhar Beg

Animals which have a back-bone are called vertebrates. Fishes, amphibians, reptiles, birds and mammals are all vertebrates. Most of the vertebrate pests come from amongst the classes of mammals and of birds. Any animal within these five classes becomes a pest if by reason of its food habits, population size, or disease harbouring propensities, it adversely affects mans' resources and well being.

The vertebrate pests are largely primary consumers and utilize the organic materials manufactured by plants. Man is also a primary consumer especially in developing countries and strives to obtain the maximum of the crop production for use by his own population. So, he is in direct conflict with other consumers who attempt to share the produce of his cultivated plants. Through agriculture, man fosters simplified systems and reduces food chains to their simplest terms. Ecosystems with simple trophic structures are usually unstable and more vulnerable to drastic ecologic change than are ecosystems with complex trophic structures. Thus agroecosystems must be carefully managed to forestall rapid takeover by opportunistic, highly adaptable species which are called weeds and pests.

A. Population Size

A population is a group of organisms of the same species occupying a particular space at a particular time. The population has various group characteristics that cannot be applied to individuals. The basic characteristic of a population that we are interested in is its size or density. The four population parameters that affect size are natality, mortality, immigration and emigration. In addition to these attributes, there are secondary characteristics of a population, such as its age distribution, genetic constitution, and patterns of distribution. The population attributes concerned with changes in abundance are interrelated as follows:



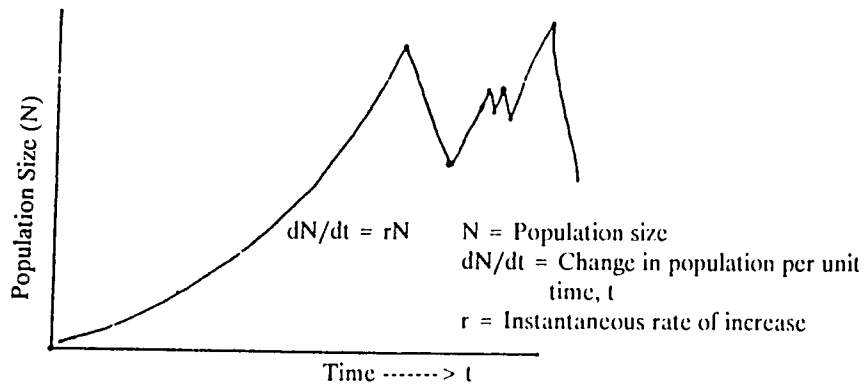
These four processes are the primary population parameters. When we ask why population density has gone up or down in a particular species we are asking which one or more of these parameters has changed.

Some of the population attributes follow certain patterns and allow us to predict the consequences of the actions taken against the population. These predictions are of basic importance in the management of pest populations.

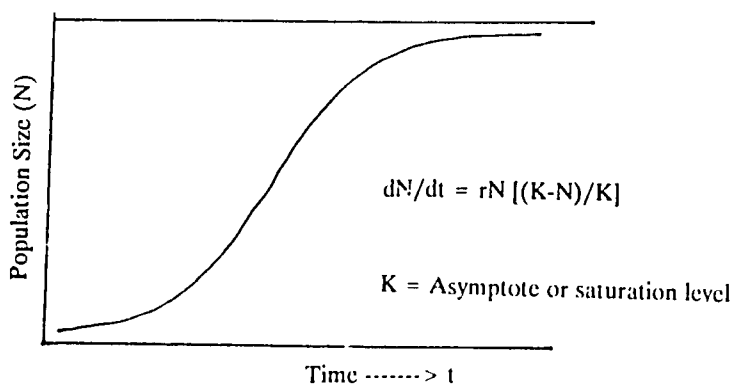
B. Population Growth.

The great reproductive potential of most pests give them a capacity for rapid population growth in favourable habitats. Many newly developing populations reveal exponential growth. But exponential growth cannot continue for long. It must and does come to an end, and the pattern in which this is achieved constitutes a population growth curve.

Some populations tend to increase exponentially until they outstrip the resources and then crash. This type of population growth can be depicted by the following J - shaped curve:



On the other hand, many populations grow in a much more orderly fashion especially in the upper, or controlling, stages of growth and the result is an S - shaped curve:



Populations which tend to exhibit J - shaped growth are often known as 'r' selected, r referring to the rate of population growth per capita in the equation dN/dt = rN. Populations with this type of growth reproduce at an early age, have large litter (clutch) sizes, reproduce frequently, and have short life spans. They can utilize new resources quickly or invade new areas when the opportunity arises but they are often subject to high mortality and sudden decline. Many pest species conform to this pattern. Thus control of pest populations usually involves management of populations with high reproductive potentials and high recovery abilities

C. Methods of Control

Most methods that are used for controlling the populations of vertebrate pests involve manipulation of mortality, natality, immigration, and emigration forces through various means.

1. Chemicals

Pesticides: The most common and effective method of attack on pests involves use of poisons in food. The substances used are of two types (i) acute poisons which kill the pest with a single dose, (ii) chronic poisons which require repeated ingestion over several days. Anticoagulants (chronic poisons) have been effectively used against rodents.

Fumigants: Fumigation is the killing of pests with gases. They are used to kill rodents in burrows in the soil.

Chemosterilants: Chemosterilants are chemicals capable of producing temporary or permanent sterility in animals. The sterile animals compete with the fertile individuals for the resources, yet they do not contribute to the birth rate. Under these conditions, the birth rate drops below the death rate and the population declines towards extinction.

Poison Dusts and Contact Poisons: Poison dusts have been used against rodents, whereas contact poisons have been used for killing birds in their roosts and for poisoning the perching sites.

2. Repellents and Scaring Devices

Scaring devices are a long-practiced art. Modern adaptations of scaring techniques utilize the basic receptor senses of the pests, namely, those of taste, sight, and hearing. Any agent affecting these senses and subsequently keeping the pests away from a food source can be classified as a repellent. Auditory and gustatory repellents are usually more effective than visual ones. Auditory and visual devices generally become less effective as the pests become conditioned to them.

A variety of devices have been used to keep pests away from crops. These include electric fences, crackers, sounds produced by machines, playback of distress and alarm calls, reflecting tapes and other visual and chemical repellents.

3. Trapping and Netting

Traps are used for mechanical killing or capturing of vertebrate pests. The most frequently used traps for killing or capturing rodents are snap traps and cage traps of several designs. Modified Australian crow traps have been effectively used for capturing sparrows and parakeets in some situations. Mist nets are used for capturing small birds and bats. Trapping and netting are employed for killing or capturing pests where use of toxicants is to be completely avoided.

4. Cultural and Agronomic Methods

Modification of cropping systems and changes in crop phenology can help limit bird damage. If crops attractive to migratory forms of sparrows occur on their migratory paths, they often receive severe damage. By altering planting and harvest dates, it is possible to escape bird attack. Planting of cereal crops resistant to bird damage on the migratory pathway may also be helpful. Awned millets and high tannin content sorghums have been found less attractive to birds.

5. Diversion Crops

At times maintenance of wastelands and grasslands in the migratory paths of depredatory birds may help in protecting the food crops more effectively than through scaring devices.

In the case of rodents, scattered plots of lucerne maintained till late April and May may help in concentrating rats and mice in these plots and make it easier in killing them.

6. Natural Enemies

Jackals, foxes, jungle cats, mongoose, owls, buzzards and hawks predate upon vertebrate pests, particularly rats and mice. But, their role seems limited as they usually fail to pull the pest populations down below the economic threshold.

Pathogens have been used in the past to kill rats. Unfortunately they are pathogenic for man also, hence their use is not advisable.

Realistic and practical control measures depend upon our knowledge of the pest species. Studies are needed on the ecology and behaviour of pest birds and mammals. Dynamics of pest populations and their relationships to various crops in different ecological zones should be investigated. In the absence of adequate ecological and behavioural knowledge, lethal methods of controlling pest populations are not only in danger of falling short of the target but may also create environmental problems. Efforts should be made to know the pest in its ecological - cultural setting and then develop methods for inhibiting its populations.

PRINCIPLES OF ECOLOGY AS THEY RELATE TO VERTEBRATE PEST MANAGEMENT

By Joe E. Brooks

A. General Nature of Environmental Responses

1. General Concept of the Ecosystem

The *ecosystem* is the basic functional unit of ecology. The ecosystem includes the non-living or *abiotic* environmental substances and gradients, such as water, carbon dioxide, calcium, oxygen, carbonates, phosphorous, temperature, moisture, winds and sunlight, and the *biotic* components - plants, animals, insects and microbes. These all interact in a fundamentally energy- dependent fashion. The abiotic physico-chemical environment and the biotic assemblage of plants, animals and microbes comprise an ecological system, or ecosystem. The ecosystem acts as a whole and all its parts are interconnected.

2. Concepts of Habitat and Ecological Niche

Ecologists use the term *habitat* to mean the place where an animal lives, and the term *ecological niche* to mean the role that the organism plays in the ecosystem. For example, lesser bandicoot rats would occupy the agroecosystem habitat of irrigated wheat, rice and sugarcane fields in the central Punjab in Pakistan. This is the rats' "address", so to speak. In these fields it is an herbivore mainly, eating the stems and grains of the several crops and it is in turn eaten by jackals, hawks, and owls. Its ecological niche is its "profession" or the part it plays in the ecosystem, in this case an herbivore, a primary consumer, serving as supplementary food for several carnivorous (meat-eating) animals.

B. Energy in Ecological Systems

1. Energy Flow in the Ecosystem

The biotic and abiotic parts of the ecosystem are linked by a constant exchange of materials - nutrient cycles - driven by energy from the sun. The basic pattern of energy and material flow in the ecosystem is shown in Fig. 1. Plants manufacture organic compounds, utilizing energy obtained from sunlight and nutrients from soil and water. The plants use these compounds as a source of building materials for their tissues and as a source of energy for their maintenance functions. To release stored chemical energy, plants break apart organic compounds into their original inorganic constituents - carbon dioxide, water, nitrates, phosphates, etc., - thus completing the nutrient cycle.

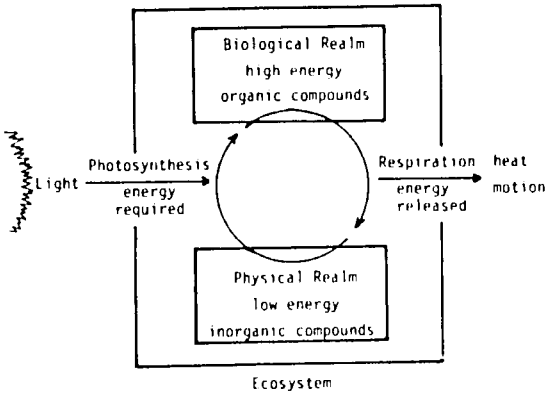


Fig. 1. Schematic diagram of the flow of energy through the ecosystem and the cycling of chemical nutrients within the system.

2. The Food Chain and Trophic Structure

Plants make their own "food" from raw materials, and are known as *autotrophs*, literally self-nourishers. Animals obtain their energy in ready-made food by eating plants or other animals; therefore they are referred to as *heterotrophs*, meaning nourished from others. The specialization of living forms as food-producers and food-consumers creates an energetic structure, called the *trophic structure*, in biological communities, through which energy flows in nutrients cycles. The food chain from grass -> grasshopper -> sparrow -> snake -> hawk depicts the path of organic materials and the energy and nutrient minerals they contain (Fig. 2). Each link in the food chain, each trophic level in the community, dissipates most of the food energy it consumes as heat, motion and sometimes, light (luminescent organisms). None of these energy forms is useful to other organisms. Hence, with each step in the food chain, the total amount of usable energy that passes through to the next higher trophic level becomes smaller.

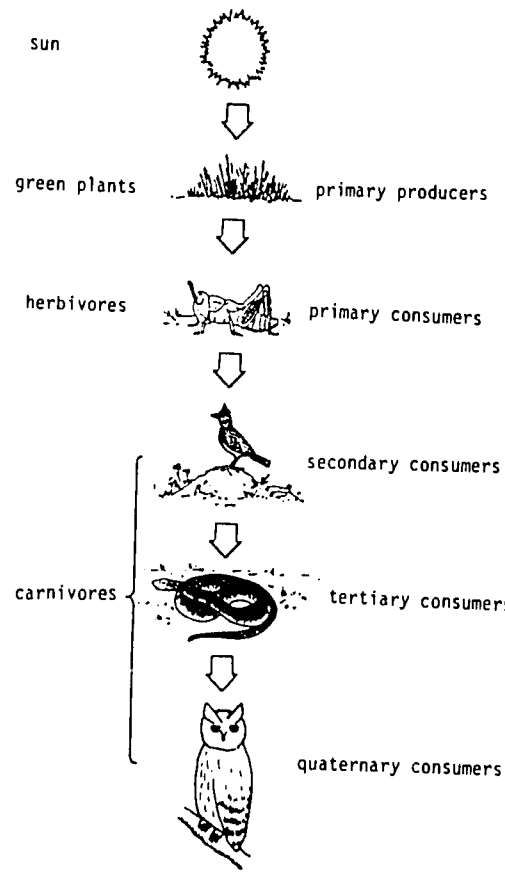


Fig. 2. A simplified terrestrial food chain showing the sequence of trophic levels.

3. Ecological Pyramids

If each trophic level in the community is represented by a block whose size corresponds to the productivity of the trophic level, and then the blocks are stacked on top of each other with the primary producers at the bottom, an *ecological pyramid* is obtained (Fig. 3). The structure of the pyramid will vary from community to community depending upon the ecological efficiency of the trophic levels. They illustrate the sharp decrease in the availability of energy at progressively higher trophic levels.

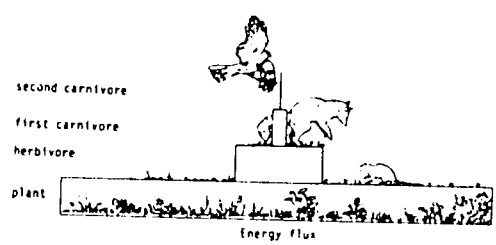


Fig. 3. Ecological pyramid based upon the net productivity of each trophic level in the ecosystem.

In vertebrate pest management we are concerned with where the pest species fit into the ecosystem, the role they play and the interactions they exert upon other members of the ecosystem. We are concerned that the vertebrate pest management methods we use have the *least impact* upon the ecosystem.

4. Concept of Productivity and Other Characteristics of Ecosystems

We have seen that ecosystems have a structure and the components perform functions which are essential to maintain the integrity of the system. There are 4 other characteristics of ecosystems that require brief mention: *productivity, maturity, stability*, and *species diversity*. To illustrate:

Compare a wheat field with a forest (Table 1). The field has very few species of plants and animals, the forest has many. The biomass (B) of the wheat field is small as compared to that of the forest. If, however, we compare the amount of energy fixed (productivity = P) in relationship to the biomass we find this ratio (P/B) is much higher in the wheat field than it is in the forest. Much of this production, of course, is harvested by man in the field, while that in the forest passes through many hundreds of species. If the field is abandoned, the wheat species soon becomes extinct and is replaced by various weeds and grasses. If the area is not burned, shrubs and trees soon invade and the area eventually reverts to forest. The field, then, is highly unstable and immature, while the forest is mature and relatively stable. The forest tends to moderate the extremes in the physical environment and provides conditions suitable for a much greater diversity of animal species than does the wheat field, where temperature and moisture may fluctuate markedly over the course of a day.

Table 1. Comparison of an agroecosystem (wheat field) with a natural ecosystem (mature forest).

Characteristics	Agroecosystem (Wheat field)	Natural Ecosystem (Mature Forest)
Number of species of plants & animals	Few	Many
Biomass	Small	Large
Productivity	High (production harvested by man & removed)	Low (production passes through many hundreds of species)
Stability	Highly unstable (wide fluctuations in animal density)	Very stable (fluctuations in animal density very little)
Maturity	Immature	Mature

Animals of immature systems may show wide fluctuations in density. There are fewer biotic controls where species diversity is low and the physical environment is less stable. The average population density for a wheat field species will be greater than that of its forest counterpart.

C. Limiting Factors in Ecological Systems

1. Concept of Limiting Factors

One of the main problems in ecology is to understand the distribution and abundance of plants and animals. We know that many plants and animals occur only in limited areas or may be abundant one year and few the next. Even in a wheat field, the distribution and abundance of the plants may vary from one part of the field to another. Explaining these differences requires an understanding of limiting factors and tolerance levels.

Any factor that slows the rate of metabolism or potential growth in an ecosystem is said to be a *limiting factor*. Years ago the idea of a limiting factor in plants was that it depended upon whatever essential element was in short supply - thus the formulation of Liebig's *Law of the Minimum*, meaning that the essential material available in amounts most closely approaching the critical minimum would tend to be limiting. This idea was extended by Shelford 70 years later to the *Law of Tolerance*, which states that the abundance or distribution of an organism can be controlled by factors exceeding the maximum or minimum levels of tolerance for that organism. This focuses upon the ecologic requirements of plants and animals in terms of climatic, topographic and biologic factors. In some instances one or more factors might be critical or might work in combination. These factors could be divided into physical, biological, and ecological factors.

2. Physical Factors

The most obvious physical factors that can limit an organism are temperature and moisture. Other physical and chemical limiting factors are light and the nutrients and chemicals present in the soil and water. Organisms have two options in dealing with temperature conditions in their habitat. They can simply put up with the temperature as it is, or they can escape from it by some form of evolutionary adaptation. Every organism has an upper and lower lethal temperature, but these vary widely from animal to animal. Consider how a burrowing rat like *B. bengalensis* copes with extremely hot dry days in a wheat field. The hot temperature at the soil surface is moderated, first of all, by the plant stand and the shade it provides. Soil is also an excellent insulator, and at a depth of 50 cm below the soil surface, the bandicoots' burrow would register temperatures only of 25 to 26°C when the outside air temperature reaches around 38 to 45°C. Furthermore, the bandicoot closes the burrow openings before dawn and effectively seals in burrow moisture and keeps out hot, dry air. The bandicoot is nocturnal and emerges to feed only after dark, thus minimizing its exposure to the daytime heat. It avoids the need for surface water by feeding upon vegetation of high water content or by utilizing the dew that collects on plants after dark.

3. Ecological Indicators

Despite the wide range in adaptation, certain plant or animal species may serve as a useful indication of environmental conditions. The rarer species make the best indicators. For example, the decline in abundance of certain rarer range grasses that are sensitive to grazing will indicate the approach of overgrazing before it becomes apparent in the grassland as a whole. The rarer, sensitive species thus act as *ecological indicators* of the effect of limiting factors.

D. Population Ecology

We now take up the more purely biological aspects of ecology, that is, the interaction of organisms with organisms in the maintenance of community structure and function. So far we have focused mainly on the role of the great physical and chemical forces in the ecosystem. What we have not yet considered are the principles dealing with interactions within and between populations, i.e., population ecology.

1. Population Characteristics

Populations are fundamental units in ecology; they are major components of communities and ecosystems. A population is a collective group of a particular kind in the community. In practice, a population is simply all of the organisms of the same species found occupying a given space, e.g., house mice in a grain warehouse or bandicoot rats in ricefields. A population has a number of characteristics unique to itself: density, natality or birth rate, mortality or death rate, age distribution, and growth rate, to name a few that we will examine.

Density: It is population size in relation to a unit of space. As density increases in a population, crowding begins, interactions between individuals become more frequent, resources become scarce and disease epidemics and death may follow.

Birth Rate (Natality): Birth rate at which new individuals are added to the population by reproduction. For most small mammals it is virtually impossible to determine the birth rate directly because we can't conduct a complete census of all animals. For birds, it may be possible to do so because all nests in a given area could be visited and the number of newly hatched young could be counted. For small mammals, therefore we usually rely on estimates made from a small portion of the population, such as trapped animals. The number of embryos in pregnant females is frequently used to estimate the birth rate but other data, such as how often females have litters and the age structure of the population, need to be determined.

Death Rate (Mortality): Death rate at which individuals are lost by death. Mortality is usually measured by starting with a group of animals of the same age, say 100 rats, and finding how long it will take for half the group to die. The rate will depend upon what age one starts with the group, since mortality rates will vary with age. Starting with juvenile animals just out of the nest, the rate could be fairly high, say 5 to 6 weeks. If the animals were adults of 3 to 4 months, the rate might be another 2 to 3 months before half died. Mortality rates are difficult to measure in the field and good studies are few.

Dispersal: Dispersal is the rate at which individuals immigrate into the population or emigrate out of the population. Population changes frequently result from large-scale movements of animals, especially young animals, into or out of an area. These movements may take place seasonally, as after a peak breeding effort or may result from weather extremes or harvesting of crops over a wide area.

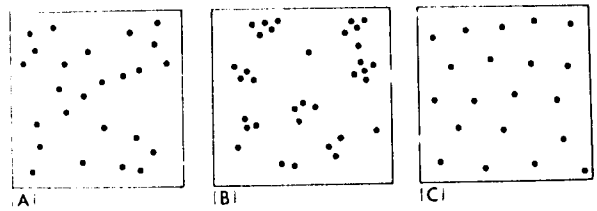


Fig. 4. Dispersion patterns of populations. A: Random. B: Clumped. C: Uniform.

Dispersion: It is the way in which individuals are distributed in space, generally in three broad patterns: 1) random distribution, 2) uniform distribution, and 3) clumped distribution (the most common in nature) (Fig. 4).

Age Distribution: It is the proportion of individuals of different ages in the population. It is important to know if the population contains a good proportion of young breeding males and females or if it is headed towards senescence, a predominance of older animals. The former indicates an increasing population while the latter would indicate one in decline.

2. Population Growth Patterns

Natural populations of animals are changing constantly. The amplitude of some numerical changes may not be detectable by casual observation or the population may reach plague proportions and then decrease catastrophically. Changes in populations can be described easily. The rate of population growth is the net result of natality, mortality and dispersal. But description and measurement are two entirely different things. Each factor contributing to population change is complex and involves interrelationships with the others. The main features can be outlined in theory.

Mainly we want to answer two things: what are the environmental factors that influence the abundance of a species in various habitats and seasons and how fast can a population increase? Is there an optional time of year for carrying out control operations? What consideration should be given to uncultivated, waste or marginal areas? At what level of reinfestation should control operations again be done? If a population is reduced by 90%, how long will it take to recover? Answers to these questions require a knowledge of population theory and an understanding of local conditions.

The growth patterns of many animal populations follow one of two general patterns: logistic or irruptive (Fig. 5A & B). There are many variations of each. Both types of population growth have a similar pattern of slow initial growth followed by a period of rapid geometric or exponential increase. In the upper stages, however, the growth curves differ markedly. Irruptive population curves are limited by sudden, often catastrophic mortality. Logistic curves achieve a gradual leveling off to a more stable asymptote. Neither pattern of population growth can be considered a law of population growth.

In general, irruptive growth patterns are found in many insect and vertebrate populations in unstable environments. They are also characteristic of disease epidemics. Logistic growth patterns are common in organisms with simple life histories, particularly in stable environments.

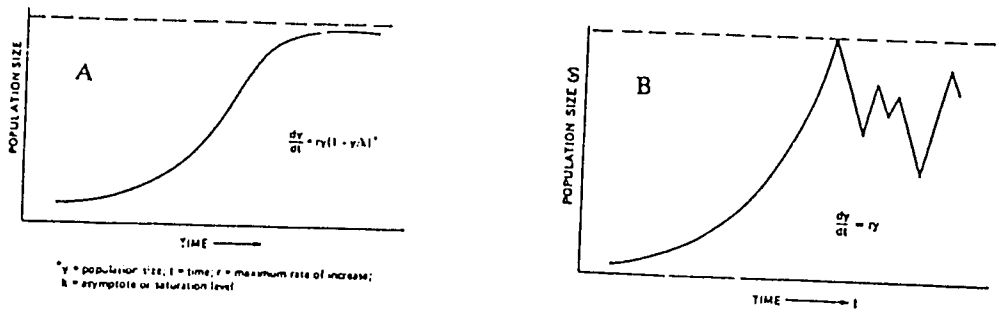


Fig. 5. Population growth pattern typical of A) logistic growth B) irruptive growth.

3. Species Interaction at Populations Level

a) Types of Interaction

At our present level of understanding, we need some framework for managing agro-ecosystems and the pest species living within. It is not realistic to consider a pest population as though it lived in a void of other species. Interactions with species other than those that provide the food base are to be expected and knowledge of these is basic to understand the total system and how it affects the target species. We will discuss only interspecific competition, predation and parasitism.

b) Interspecific Competition

Interspecific competition occurs when two or more species require a common resource that is in limited supply. It is assumed that either closely related or ecologically similar species will compete most intensively because their requirements are most similar. We have a principle that two species cannot occupy the same niche indefinitely: one will eventually exclude the other.

The main evidence for competition in the field comes from occasional observations where one species has replaced another (Norway rat vs. roof rat in Europe and USA and bandicoot rat vs. roof rat in India, Bangladesh and Burma). The mechanisms of competition are poorly understood and it is seldom possible to identify the resource which is presumably limited. Species do exist together in many cases, however - what patterns do we see? In wheat fields in Pakistan are found bandicoot rats, short-tailed mole rats and house mice. One pattern that seems evident for coexisting-species is to differ in body size; for example 20 g for house mice, 125 g for mole rats and 250 + g for bandicoot rats.

c) Predation

A predator is an animal that kills another animal for food. Since predation is a direct cause of mortality, its possible effects on population dynamics should be considered. The effect of predation on vertebrate populations is one of the most controversial topics in ecology. The problems of assessing the consequence of predation (primarily by carnivores, raptors, and snakes) on mammal populations are that they have their own density- limiting mechanisms and it is difficult to separate the effects of predation on the population from these inherent density-limiting factors.

One viewpoint about predation is that in certain circumstances predators may control a mammal population which has a high degree of vulnerability (e.g. lack of cover) and the predator populations have an alternative food supply. Otherwise, the predators would destroy their own food

supply. Another, more general viewpoint, is that predators mainly take surplus animals that would soon die anyhow and if predation does reduce a prey population, the prey compensate by higher levels of breeding and increased survival of young animals. Opinions vary widely so attempting generalizations about predation are rather fruitless. As an example, past attempts to control rats by introducing the mongoose to islands in the Caribbean and to Hawaii have had no obvious success and have produced undesirable side-effects.

d) Parasites and Disease

The term parasite covers a wide variety of relationships whereby one organism lives at the expense of another, contributing no obvious benefit to the relationship and being potentially harmful to the host. Ectoparasites, such as fleas, lice, ticks and mites seldom debilitate the host unless they transmit a possibly lethal disease. More restricted use of the term parasite is applied to those organisms obliged to spend some part of their life cycle in intimate contact with the tissues of the host.

Parasites of mammals, by the above definition, could be viruses, bacteria, fungi, protozoans, helminths and insects. Of real concern is the real or potential pathogenicity of the parasite, since it is evident that in most cases the survival of the parasite and its progeny depends upon the continued survival of its host. With few exceptions, a parasite that kills its host also kills itself.

The use of pathogens to control pest mammals is an old idea. In practice, virtually nothing exists that the host does not eventually adapt to. Myxomatosis introduced into rabbit populations in Australia is the most spectacular example of biological control in mammals. About 20 years after it was introduced, the rabbit population in Australia had largely recovered, however. Possibilities for biological control of pest mammals with pathogens remain largely hypothetical. No good organism has been found, for example, in rat control, that the rat populations do not adapt to in a short time. Meanwhile, the hazards of the organism producing disease in humans, pets and livestock preclude the use of such techniques.

E. Applied Ecology

Applied ecology is the use of ecological tools and knowledge to most effectively and efficiently manage ecosystems for the maximum benefit of most organisms. Ideally, this would mean that mans' activities would have the least impact possible upon natural ecosystems. Unfortunately or not, mans' impact on natural ecosystems has been enormous and generally to the detriment of most organisms that originally lived there. The agricultural ecosystem, or simply agroecosystem, that man creates out of natural systems, is a finely-tuned, greatly simplified and highly unstable system.

1. Agroecosystem

a) Monoculture

The most productive and, in some ways, easiest agroecosystem for man to manage is the monocultural system, where one crop variety is grown over a vast area. This is one of the most unstable of all agroecosystems, however. Pests, plant diseases, effects of weather extremes, all can operate to effectively cause an almost total crop failure in times of adversity.

b) Crop Diversity

Ideally, the agroecosystem should consist of diversity and intermixture in crop types, and a large spread in planting dates to create a more stable system, less susceptible to catastrophic failure. Luckily, this is what we see in the diversified agriculture in the irrigated areas of the Punjab and Sind Provinces, less so in the barani (rainfed) areas of Punjab and NWFP. However, crop diversity can bring with it a curse as well as a blessing. By having several varieties of food crops in the fields,

rodents, wild boar and pest birds are given a variety of crop types of which to attack in season, to hide in, etc. and then move on to the next crop type as the growing season advances.

2. Vertebrate Damage Control

It is essentially impossible to attempt to eradicate vertebrate pests from crop growing areas. There are too many marginal habitats, waste areas, and "reservoir habitats" in which they will survive even if rigorously eliminated from crop fields. Attempts at total eradication are not economically feasible; the first 90% of population reduction may be relatively easy and inexpensive while the last 10% would cost a fortune to achieve, if possible.

The key to vertebrate damage control in agroecosystems is to intervene as little as possible and still be able to reduce crop damage. This may mean reducing the pest populations in the crops just prior to the damage period. It may mean repelling the pest species only during the short period that the crops are vulnerable to attack. It might be as simple as exclusion measures to keep pests out of field crop situations, such as low fencing to keep desert hares from chickpea plots or electric fencing to keep wild boar out of maize fields. It might mean the simultaneous planting of one variety of field crop or advancing the date of sowing so as to avoid migratory bird populations. Other alternative methods in suppressing field populations of mammal pests involve habitat modification, e.g., removal of weed patches and scrub areas. This will create less suitable conditions for the survival of the pest species during periods when the fields are fallow.

3. Rodents and Human Diseases

Diseases and infections naturally transmitted between vertebrate animals and man are called zoonoses. Many are known to occur in rodents although not all seriously affect human health. Some diseases carried by rodents, such as brucellosis, are hardly ever transmitted to man. In contrast, the effects of a disease like plague can be devastating to the human populations and the role of rats in its transmission is extremely important.

Under natural conditions, the infections disease organisms, the host (rats) and the vector (fleas, ticks or mites) exist together as part of the ecosystem. The three kinds of organisms have a set of ecological requirements such as climatic, edaphic and vegetation conditions, and live together in a balanced relationship. The infection in rats and other rodents is often maintained permanently only in restricted areas (foci) and these are often in situations uninhabited by man so that disease transmission does not take place. Infection only occurs when man moves into these areas. For example, this could occur due to changing land use, e.g., forest clearance, agricultural development or urbanization. This brings man into a closer, more permanent association with the disease focus. Sometimes modification of the habitat can create a more beneficial environment for the host.

Plague transmission in South Africa illustrates well the above mentioned example. Man there has inadvertently created suitable habitats for the multimammate mouse (*Praomys*) in his farm buildings. *Praomys* is not the primary host of plague in this area. The main reservoir is the highveld gerbil, *Tatera brantsi*, with transmission of plague through its flea, *Xenopsylla philoxera*. This gerbil has little or no contact with man. However, when an outbreak of plague occurs, many gerbils die and *Praomys* move into the empty burrows. Because this species has a wider ecological range than the gerbil, its range extends into human habitations. Plague then spreads through this species populations and into close association with man. Spread is often accelerated through the house rat (*Rattus*) population with which the multimammate mouse comes into contact. Part of this description has been oversimplified but it illustrates the ecological complexity of the transmission route.

PRINCIPLES OF MAMMALOGY AS THEY RELATE TO MAMMAL PEST MANAGEMENT

By Mirza Azhar Beg

A. Characteristics of Mammals

Mammals are highly evolved vertebrates and form the dominant animal feature in the ecology of the present day world. Mammals differ from reptiles and resemble birds in that they are warm- blooded, have a four chambered heart, and have a complete double circulatory system. Mammals are more highly evolved than birds in method of reproduction, in parental care, and in greater development of intelligence. Some of the characteristic features of mammals are as follows:

1. Hair is present in at least some stage of development of all mammals. The primary function of hair is for insulation and in maintaining a constant body temperature.

2. Mammals have external ear openings, surrounded by a pinna or conch. The pinna is reduced or absent in some species that live underground or in water.

3. Mammary glands (milk glands) are present in all females. The production of milk and suckling of the young is unique to mammals.

4. The young are born alive in all mammals except the egg-laying monotremes.

5. Dentition in mammals is generally heterodont, that is, the teeth are modified in shape and size to serve specialized functions.

B. Classification

Classification is the naming and organizing of a group of related animals. The purposes of classification are: 1) to provide a convenient label by which an animal is known all over the world and 2) to show affinities or relationships. Roughly 4000 species of mammals are currently recognized. The Class Mammalia consists of 19 orders of living mammals, but not all mammalogists agree on this arrangement. In Pakistan about 158 species of mammals are represented. The important mammal pests in Pakistan belong to the following four orders:

Order	Species
Insectivora	House shrew (*Suncus murinus*)
Lagomorpha	Desert hare (*Lepus nigricollis*)
	Collared pika (*Ochotona rufescens*)
Rodentia	Northern palm squirrel (*Funambulus pennanti*)
	Indian porcupine (*Hystrix indica*)
	Indian gerbil (*Tatera indica*)
	Desert jird (*Meriones hurrianae*)
	Libyan jird (*Meriones libycus*)
	Soft furred field rat (*Millardia meltada*)
	House rat (*Rattus rattus*)
	Norway rat (*Rattus norvegicus*)
	House mouse (*Mus musculus*)
	Lesser bandicoot rat (*Bandicota bengalensis*)
	Short-tailed mole rat (*Nesokia indica*)
	Murree vole (*Hyperacrius wynnei*)
Artiodactyla	Wild boar (*Sus scrofa*)

Orders are based upon major differences in limbs, digits and cranial modifications, primarily the teeth (Fig. 1).

C. Distribution

It is obvious that even on the individual continents, that not all, or very few, mammals are rather evenly distributed. Some species have a wide geographical range; others are quite limited in where they occur. In general, the geographical distribution of a species depends on its place of origin, on the historical opportunities it has had to disperse, or invade, other suitable areas, and on its success in surviving environmental changes, including competition from other species. If a successful species is one that has a wide geographical range, then the most successful mammal species are those that are closely commensal with man, i.e. the house mouse, Norway rat and roof rat. These three species occur worldwide. Another successful commensal or developing commensal is the Polynesian rat, *Rattus exulans*, which was presumably carried on the colonizing canoes of the Polynesians to most islands in the Pacific, including New Zealand and the Hawaiian Islands. Examples of developing commensals in Asia are the lesser bandicoot rat, *Bandicota bengalensis*, now both a field and urban rat in parts of India, Bangladesh and Burma, and the Asiatic house or musk shrew, *Suncus murinus*, which has apparently been spread via shipping from Madagascar in the west to Guam in the east.

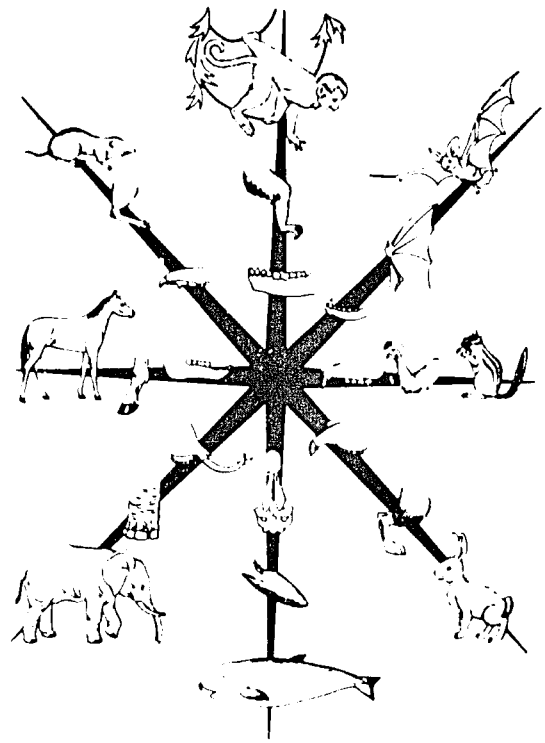


Fig. 1. The order of mammals is based on major differences in limbs, digits, and cranial modifications.

Establishing the place of origin for a species can be tricky and speculative. Place of origin is often deduced from fossil evidence. It also is assumed that the historical home is where the individual species shows the most diversity (i.e. has had the longest time in which to evolve). This criterion may not necessarily be true, however, since it is usual to find the highest variety of adaptation in habitats affording the greatest variety of niches.

Mammals can survive dispersal only when they move to an area within their physiological and ecological tolerances. Furthermore they must have the opportunities to disperse, i.e., land bridges when the oceans were lower, or using mans transport and communication networks (house mice, rats and musk shrew), or even being able to survive on floating rafts long enough to reach either islands or the mainland.

Competition from other species can change an animals' range. The classic competition between the roof rat and the Norway rat was shown by the latter species displacing the former in the 1950's in rural Georgia, USA. The lesser bandicoot rat displaces both the roof rat and the Norway rat in cities in India and Burma.

D. Reproduction

Reproduction is the mechanism by which a species is maintained from generation to generation. In mammals the process of reproduction is sexual. The reproductive cells are the ova or eggs and the spermatozoa. These are produced in separate animals, the ova by the ovaries in the females and the sperm by the testes in the male. Associated with the ovary and the testes are a number of accessory reproductive organs.

The position of the testes in the various species of mammals is varied. Most kinds have a scrotum. In some, such as the pig, the testes remain in the scrotum throughout the adult life. In most rodents the testes are in the body cavity. Only during the breeding season do they descend into the scrotum.

The bone called the os penis, or baculum, is found in the penis of many bats, most rodents, and most carnivores. The os penis has been used as an aid in identification of closely related species and as an aid in determining the approximate age of an individual animal.

Most kinds of mammals have breeding seasons restricted to a definite time of year. This season is usually at a time most advantageous for the pregnant female and the newborn young. Even in those species that breed round the year, breeding activities are stepped up during periods of better environmental conditions.

Most of the rodents in the Punjab cease to reproduce during the colder months of the year. During the period of complete sexual inactivity, the gonads of the females, and in some cases, of the males, undergo involution, reduce in size and cease to form gametes. In males the testes become abdominal, that is retract into the body cavity. The accessory and secondary sex structures also retrogress during this period of inactivity. Some times a single species may show geographic variations in the reproductive cycle. The same species of rats that are known to breed throughout the year in Sind, cease to reproduce in Punjab during December and January.

In most female mammals there is a recurrent estrous or heat cycle. During this period the female is receptive to the male and fruitful coition is possible. The ova are usually discharged from the ovary late in the estrous period. If fertilization takes place at this time pregnancy normally occurs. Lactation follows gestation. In certain species parturition is followed immediately by another estrus cycle. Such mammals are termed polyestrus. Mammals with only one breeding season each year are called monestrus. At least all the rodent pests listed earlier are polyestrus.

The period of time that the embryo is carried in the body of the mother is called gestation. Much variation exists in the length of the gestation period. The lengths of the gestation period in some pest species are given in Table 1.

The reproductive capacities of mammals vary greatly. In general, small mammals, like rodents, with their early maturation, short gestation, frequent estrus and large litters have considerable potential for increase. The lesser bandicoot rat, *Bandicota bengalensis*, after a maturation period of about three months followed by a gestation period of 23 days, has a litter of young ranging upto 18 in number. A single female could have as many as 10 litters in one year. The Norway rat is known to have as many as 20 young in one litter.

In spite of its much larger size, the wild boar has a great potential for increase. It has a gestation period of about 112 days, a litter size of 4 to 6 young and the females may start breeding between the ages of 6 months to about 1 year.

Table 1: Gestation Period and Litter Size of Mammal Pests

Species	Gestation Period (days)	Litter Size
House shrew	29-31	3-4
Collared pika	30	4-9
Northern palm squirrel	40-42	2-5
Indian porcupine	112	2-4
Indian gerbil	22	2-9
Desert jird	28-30	3-9
Libyan jird	-	3-4
Soft-furred field rat	21	3-10
House rat	21	3-12
Norway rat	21-22	9-10
House mouse	19	3-8
Lesser bandicoot rat	23	4-18
Short-tailed mole rat	30	3-8
Wild boar	110-115	4-6

E. Populations

The study of populations is particularly important, as it facilitates the description of many ecological processes in quantitative terms. The breeding potential of most mammals and especially of the pest species is much greater than the space they occupy will support. The Norway rat has a gestation period of about 21 days. It has 3 to 6 young per litter and an average of ten litters per year. A pair with reproductive parameters defined above would produce a total of 359709482 descendants in three years. But, environmental resistance does not permit such uninhibited growth for very long. Factors like restricted food supply, limited space, adverse climate conditions, intra- and interspecific competition, predators, parasites, and diseases keep populations in equilibrium with the environment. However, in man-made ecological systems the factors of the environment that oppose unrestricted growth are usually weak and fail to restrict pest populations, at least, for some time. It is then the pests inflict maximum damage to cultivated plants.

The actual size of mammalian populations is difficult to measure. In only a few cases it is possible to count all individuals present in a given area. Hence, mammalogists resort to various sampling techniques and formulate formulae for obtaining a reliable estimate of the actual population size. Furthermore, population densities change in space and time. Even then it is often desirable to have data concerning the estimate of problem population size and structure. This is especially true in the case of pest mammals where such data are essential for population management procedures.

F. Population Composition

To understand the biology of a pest we need information as to sex ratio, age distribution, and reproductive status of its members. Data on age distribution are hard to secure. A number of techniques have been developed for estimating age of specimens caught from the field. In many species it is easily possible to recognise adults and immatures. Even the information regarding proportions of these two age categories in a population is useful in determining the effective breeding population.

Among most of the smaller rodents, life expectancy is extremely short. Experiments have shown that individuals seldom live longer than a year in the field. But, with their exceptionally high reproductive potentials, they are capable of replacing themselves rapidly. So removal of rats from a field will hardly make a dent in their population, unless and until there is a frequent removal in good numbers.

G. Behaviour

1. Territoriality and Dominance Hierarchies

Two aspects of social behaviour which are of considerable significance in population ecology are territorialism and dominance hierarchies. Most mammals have an area of ground which they regularly patrol and with which they are well acquainted. Here they come to know the sources of food and water, escape routes and resting sites. This area is the home range. Within it there may be a smaller core area which is used more intensively than the rest. This area is called a territory. It is a defended area. Territories are commonly found in species having regular resting sites, such as rodents that live in burrows.

Whereas the function of territories is to allot resources on spatial basis, dominance hierarchies allot resources on an individual priority basis within the same physical space. Dominant animals have priority access to food, mates, nest sites and resting locations. Both territorialism and dominance hierarchies affect the abundance and distribution of animals, their reproductive patterns, and their mortality patterns. Many studies of territorial or rank-oriented species have shown that individuals without territory and low ranking individuals have less reproductive success and higher mortality rates than those who hold territories or have higher ranks.

2. Exploratory Behaviour

Mammals are in the habit of exploring their home range. In this way they gather information about the place where they live and this information may be used later. A rat in a familiar environment readily avoids predators because it can quickly run for cover. Rats forced out of their home ranges following harvesting of crops are more at risk of falling prey to predators than those living in their home ranges.

Rats and other mammals move in their home range using the same pathways. If a strange object, for example a trap or a pile of poisoned food, is placed in a familiar area, the rats generally avoid it. When a new food in an area occupied by Norway rats is placed, it may at first be totally avoided. Later it is sampled in small amounts. If poison is present, the sampling often leads to consumption of a sub-lethal dose. The ill effects of the poison are associated with the smell or taste of the food that contained the poison. In this way the rat learns to avoid particular kinds of food and poison. This applies not only to the Norway rat but also to most of the other pest mammals, including the wild boar.

3. Daily Activities

In the normal life of a mammal, at least some effort is devoted to the following types of activities: securing food and water, rest, play, defense of territory and sanitation. The proportion of time devoted to each of these activities varies with the season, local conditions, and the particular species of mammal. Mammals show great variations in the daily pattern of activity, not only as to the time of day in which these activities occur but also as to the duration of the activity. Animals like shrews are active almost all the time, day and night, but their activity periods are interrupted by periods of rest. Species such as squirrels, which are active only during daylight hours, are called *diurnal*. Species such as most bats and many rodents are active only at night, and are termed *nocturnal*.

H. Economic Relationships with Man

Mammals are so interwoven with mans' economy that it is generally impossible to give any concise estimate of their worth in either a positive or negative sense. Here are listed only a few of the ways in which mammals influence man's activities.

Mammals have multiple effects on the physical environment. One of the more obvious effects come from their digging in the soil. Rats and porcupines make burrows in canalsides, ditches and embankments that often allow breaching and the escape of valuable irrigation water. The rooting activities of wild boars are well-known and they frequently virtually eliminate certain species of rare or endangered plants.

Some mammals are quite destructive to newly planted forestry seedlings, while others girdle and kill orchard trees. Many crops are damaged and consumed by a variety of mammals, ranging from rats and mice, to wild boars and jackals, to baboons, elephants and rhinoceros. In these activities, they come into direct competition with man for his food resources.

Likewise, wild mammals can and do compete with domestic animals for forage and water. They are also implicated as predators, i.e., mongoose capturing and eating young chicks or coyote attacking sheep.

Mammals are used for food, fur and for sport hunting. Wild mammals are not nearly so important as a food source today as they were in centuries past, thanks largely to the domestication and large-scale breeding of beef cattle, sheep, goats and, in non-Muslim countries, of pigs.

Mammals fur continues to be utilized. The most obvious example is the Eskimo's use of the fur of the polar bear as protection against extremely cold weather. Hides of mammals find a variety of uses, mainly in the making of shoes, jackets etc.

Finally, many wild mammals, especially rats and mice, are capable of acting as reservoirs of diseases and of directly or indirectly transmitting these diseases to humans and to domestic animals. Examples are bubonic plague, murine typhus, tularemia, Rocky Mountain spotted fever, rabies, hoof and mouth disease, etc. The monetary value of economic losses of man through these diseases is beyond estimate.

MAMMAL PESTS OF PAKISTAN: CLASSIFICATION

By Abdul Rauf Khokhar

A. Classification

Classification is the naming and organizing of a group of related animals. The purposes of classification are to provide a convenient label or name by which an animal is known to scientists and laymen all over the world and to show affinities or relationships among groups.

The basic unit of classification is the *species*. Our present idea of a species is that it is an assemblage of animals that freely interbreed, or do so when they meet, and do not interbreed with members of other assemblages. The orderly arrangement of species into groups or categories on the basis of their relationships is what is commonly called "classification". Animals are grouped into larger categories in a systematic framework, or hierarchy. In zoology, the hierarchy is a sequence of 7 levels: kingdom, phylum, class, order, family, genus and species. For example:

Kingdom Animalia
Phylum Vertebrata

Class Pisces (Fishes)
Class Amphibia (Amphibians)
Class Reptilia (Reptiles)
Class Aves (Birds)
Class Mammalia (Mammals)
Order Rodentia
Family Muridae
Genus *Bandicota*
Species *bengalensis*

Species names always consist of two words: the first is the genus name and the second is the descriptive species name.

The Class Mammalia consists of 19 orders of living mammals, but not all mammalogists agree on this arrangement. Mammals are those animals that feed their young with milk and have hair on the body at least in one stage of development. Moreover, the diaphragm muscle separates the heart and lungs from the rest of the abdominal cavity.

The Class Mammalia is divided into several orders but here the discussion will be limited only to those orders which are important from a vertebrate pest point of view especially in Pakistan. These orders are as follows:

Chiroptera - bats (insectivorous and frugivorous)
Insectivora - shrews
Rodentia - rats, mice, squirrels and porcupines
Lagomorpha - rabbits, hares and pikas
Artiodactyla - wild boar
Carnivora - mongoose, jackal

B. Order Rodentia

Most mammal pests belong to the order Rodentia, particularly those members of the family Muridae. Rodents are characterized by the presence of a typical dentition. These dental characters separate the rodents from the representatives of all other orders of mammalia. The dentition of rodents consists of two pairs of long chisel-shaped front teeth known as incisors. The incisors on both the upper and lower jaw are followed by a toothless gap known as the *diastema* (Fig. 1). Behind the

diastema come a set of grinding teeth known as the molars. In some rodents, for example squirrels, molar teeth can further be divided into premolars and molars.

The incisors are the main structure in the rodents which are used for causing the great crop damage and losses. These incisors grow continuously throughout life. The front surface of each incisor is covered by a hard material known as enamel and behind this is a softer portion known as dentine. The chisel-like edge of the incisors are constantly being worn down by the gnawing activities of the animals. Rodents often grind their incisors together to keep them sharp.

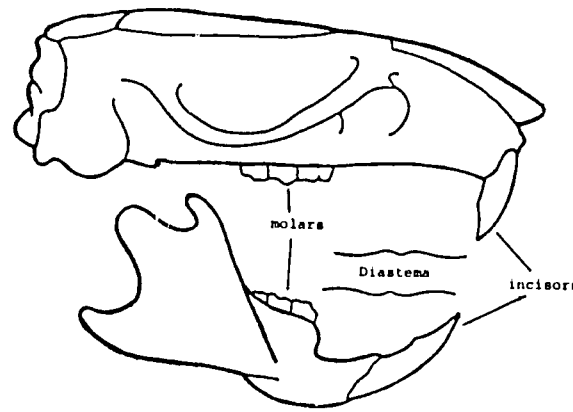


Fig. 1. Skull of a rodent, showing incisors, molars and diastema.

If the nibbled food of the rodent is not preferred, it will not be passed onto the grinding molars but instead will be ejected out of the sides of the mouth. In this feeding behavior, the diastema, which is lined by small hairs, acts as a sieve so that only finely divided food particles are allowed to pass to the grinding molars before being swallowed.

The Order Rodentia is comprised of many genera and species which are of economic importance. These are:

Bandicota bengalensis, lesser bandicoot rat
Nesokia indica, short-tailed mole rat
Millardia meltada, soft-furred field rat
Mus musculus and other *Mus* spp., house mouse
Tatera indica, Indian gerbil
Meriones hurrianae, desert jird
M. libycus, Libyan jird
Rattus rattus, roof rat
R. norvegicus, Norway rat
Hystrix indica, Indian crested porcupine
Funambulus pennanti, Northern palm squirrel
Hyperacrius wynnei, Murree vole

C. Order Lagomorpha

Animals of the order Lagomorpha resemble rodents in overall dentition except there is a smaller second pair of incisors located directly behind the main incisors on the upper jaw. The smaller incisors lack the cutting edge and are typical of the rabbits, hares and pikas.

Young of rabbits are born helpless, naked, and with the eyes closed while the young of hares are born fully haired and with open eyes. The young hares are able to run few minutes after their birth.

There is no true rabbit in Pakistan. Only two species of lagomorphs are considered as vertebrate pests. These are:

Lepus nigricollis - the desert hare
Ochotona rufescens - the collared Afghan pika

D. Order Artiodactyla

The order Artiodactyla is characterized as being even-toed hoofed mammals, and includes the camel, goat, sheep, and wild boar.

Wild boar, *Sus scrofa* (Family Suidae), is the only representative of the order Artiodactyla that is a pest in Pakistan. Wild boar is a medium-sized mammal with pointed long head, short neck, and stocky body. The snout is mobile and truncated terminally with a disc of cartilage in the tip. The canines in the male become elongated and are used as defensive tools when fighting. The eyes are small. Wild boar is a gregarious animal.

Wild boar has increased to become a significant pest in Pakistan within the last 30 years, due to development of irrigated forests and sugarcane crops - both affording excellent shelter for wild boar and for breeding sites. Wild boar does heavy damage to a variety of crops, including forest seedlings, sugarcane, maize, wheat, rice and potatoes.

E. Order Carnivora

In Pakistan, carnivorous pests mainly are jackals (*Canis aureus*) and mongoose (*Herpestes auropunctatus*). Jackals spend their days lying up in thickets and dense clumps of vegetation. They usually travel singly or in pairs, and occasionally in groups. Although they are carnivores, they actually subsist on all kinds of food, and thus are more like omnivores. They have been known to damage crops, such as melons, sugarcane and maize by feeding on them. They also prey upon smaller animals, catching and eating rats and mice, but also killing and eating chickens.

The small Indian mongoose is a carnivore. It preys upon other small mammals, birds, reptiles, frogs, insects, and has been known to attack and kill young chicks. Mongoose can feed both by day and night. The mongoose is a very bold, solitary hunter, and often kills prey much larger than itself. It has a good sense of smell and is able to follow the trail of prey animals to their burrows.

F. Order Chiroptera

The order Chiroptera is sub-divided into two groups, the insect-eating bats and the fruit-eating bats. Bats are the only mammals to have truly mastered flight. The insect-eating bats orient themselves by echolocation, using ultrasonic pulses as a form of sonar. The fruit-eating bats, in contrast, normally orient themselves by the use of sight, although one genus has a simple echolocation system. Fruit bats locate fruit by smell.

Fruit bats roost in large groups and in various habitats, depending on the species. They are generally nocturnal, though they may appear on dark, gloomy days. Fruit bats are quite variable in size, ranging from the largest bats in the world to some considerably smaller than the largest insect-feeding bats.

Fruit bats have a rather generalized face; there are no nose leaves, the eyes are normal and the external ear is not specialized. The important fruit bat from a vertebrate pest viewpoint in Pakistan is *Rousettus aegyptiacus*. This bat frequents a variety of diurnal roosts - from natural caves, often near the seashore, underground irrigation tunnels (karezes), open wells or inside abandoned buildings. In Karachi, ripe guava is the principal food of this species. The seasonal nectar of mango flowers is also susceptible to attack by fruit bats. Not much is known about the breeding habits of fruit bats.

IMPORTANT RODENT PESTS OF PAKISTAN: ECOLOGY AND DISTRIBUTION

By Mirza Azhar Beg and Iftikhar Hussain

One of the outstanding characteristics of most of pest rodents is their capacity for rapid population growth. This they achieve by having a short gestation period, post-parturient heat, large litter size, by producing several litters in a short period, and having rapid sexual maturation. Among other important attributes of a pest species is their ability to live under varied conditions of environment and utilize a wide variety of foods. Whenever and wherever the pests have the conditions of the environment in their favour they increase their numbers rapidly and naturally their exploitations under such circumstances bring misery to the farmers.

Below are given brief descriptions of the identification, distribution and ecology of 11 species of rodent pests which exact their share of mans food available in the field and/or stored inside structures.

A. Lesser Bandicoot Rat (*Bandicota bengalensis*)

Description: The lesser bandicoot rat is perhaps the most common field rat to be found in Pakistan. The bandicoot is a medium-sized, dark brownish-grey colored, coarse-furred rat (Fig. 1). It is a robust rat, with rounded head, broad muzzle and a tail shorter than head and body. It may weigh up to 300 g. The head and body length ranges from 160 to 210 mm in adults; the tail varies from 130 to 180 mm. Mammae range from 12 to 20. It is a fierce and aggressive animal and often is seen threatening intruders by grunting from inside its burrow. It is a good swimmer and takes readily to water.

Fig. 1. The lesser bandicoot rat.

Distribution: The bandicoot rat was formerly confined to better watered tracts along the Himalayan foothills in the Punjab and N.W.F.P., and the coastal plain of Sind. At present, it is known to occur in the following districts: Thatta, Badin, Hyderabad and Tharparkar in Sind; Sahiwal, Jhang, Sargodha, Faisalabad, Sheikhupura, Gujranwala, Sialkot and Rawalpindi in Punjab; and Hazara, Mardan, Peshawar, Malakand and Kurram in the N.W.F.P. (Fig. 2). The rat seems to have invaded the districts of central Punjab during the last three decades. Multiple cropping practices involving sugarcane and rice and formation of marshy habitats due to seepage from the irrigation canals seem to have helped the rat in extending its range to places where it did not occur earlier.

Habitat: Inhabits cultivated fields and may occur in areas under natural vegetation near crop fields. In irrigated fields it prefers to burrow in the bunds. Found around, but not inside, farm structures in Pakistan.

Habits: Nocturnal, semi-fossorial. An exceptionally versatile, widespread and common rat. The bandicoot rat is perhaps the most destructive rodent pest of field crops in Pakistan. It infests a variety of crops but the three major crops are its main targets. In rice fields it burrows both in the bunds and in the fields. When the field are very wet, the burrows are largely confined to the bunds. As the fields dry, fresh burrows are dug in the fields or the bund-burrows themselves are extended into the fields. The burrows go to a depth of about 1 m and may have an expanse of 15 m. It destroys the crop at every stage of growth: damage is done first to shoots, milky pulp of the ear heads and finally to the

rice grains stored in its burrows. An average of 3.2 kg of rice grains may be stored in the burrow systems. There have been recorded an average of 30 burrow systems in a hectare of rice fields in central Punjab.

The rat invades the wheat crop in large numbers in the flowering stage. The population rapidly builds up and soon the rat gains a clearcut numerical superiority over other species. It feeds on the tillers, ripening earheads, and ripe grains. Burrows occur both on bunds and in fields but at about harvest time the number of burrows in the field increases greatly. Ripe grains are hoarded in the burrows. The longer the harvested crop is left in the field the greater is the loss due to hoarding activities of the rat. An average of 13 burrow systems of the bandicoot rat have been recorded from a hectare of wheat fields in central Punjab.

The bandicoot rat is also a very serious pest of sugarcane. The rat damages the canes by eating portions of the stalk internodes, usually near the base. In the case of lodged canes, several of the internodes may be damaged.

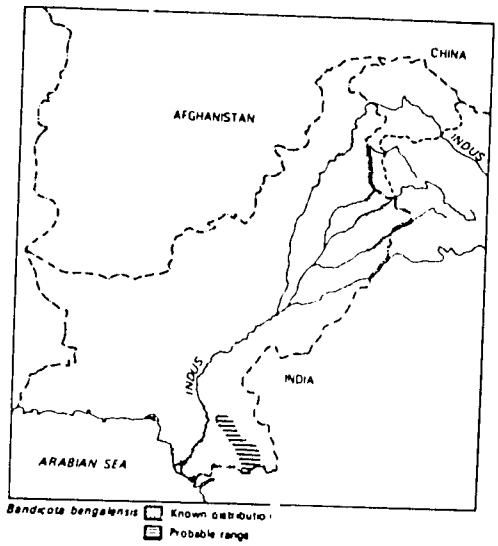


Fig. 2. Distribution map.

In Sind the bandicoot rat breeds throughout the year. In central Punjab breeding stops during December and January. Information regarding the proportion of pregnant females in annual samples, average embryonic litter size, number of litters produced per year and the annual production is given in Table 1. Undoubtedly, the bandicoot rat is a highly prolific rat.

In Pakistan bandicoots are largely pests of agricultural crops and only rarely live in buildings. This is in contrast to the situation in India where they have become a major urban pest.

The average diameter of the home range of the bandicoot has been estimated to be 50 m. Long range movements are helpful in effective exploitation of the changing resources of the habitat.

The major enemies of the bandicoot rat in the croplands are the jackals, foxes, mongoose, jungle cats, owls and snakes.

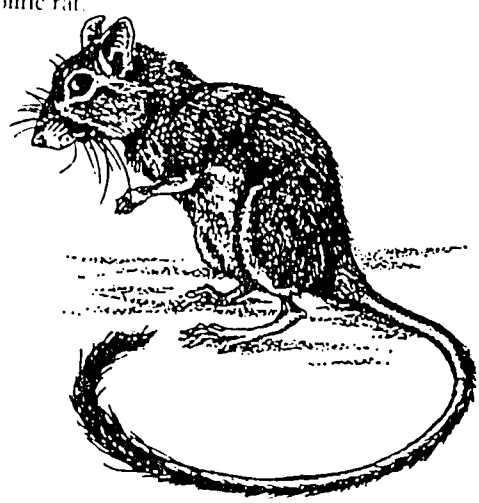


Fig. 3. Indian gerbil.

B. Indian Gerbil (*Tatera indica*)

Description: The Indian gerbil is a medium-sized rat with long hind legs. The body fur is long and silky. The back is sandy-brown and the belly is white. The tail is hairy, with long tufts near the end and with a lateral light colored band running down each side of the tail. The eyes are black and large (Fig. 3). The tail is generally 120 percent of the head and body length. The size of the adults excluding tail is 150-170 mm. Generally males are heavier than females, weighing from 150 to 220 g.

Table 1: Some Reproductive Parameters of Rodent Pests of Pakistan

Species	Proportion of Pregnant Females in Annual Sample	No. Litters Per Year	Average Litter Size	Young Produced/ Year/Female
B. bengalensis	47.4	10.2	7.4	75.2
T. indica	33.6	7.0	6.8	47.3
M. meltada	54.1	12.3	5.3	65.1
M. musculus	51.1	12.4	6.2	76.6
N. indica	30.0	6.4	2.4	15.4
R. rattus	46.0	10.5	6.2	65.0
R. norvegicus	15-31	2-6	8-10	19-56
M. hurrianae	34.4	5.5	4.9	27.0
M. libycus	-	-	3-4	-
F. pennanti	25.2	3(?)	2.3	-
H. indica	-	2(?)	1-4	-

<u>Distribution</u>: The Indian gerbil is found throughout Pakistan except in sand dunes and rocky mountains (Fig. 4). It is found wherever it can burrow in dry soil and feed. It is found throughout the irrigated areas of the Punjab and in some villages it has become semi-commensal.

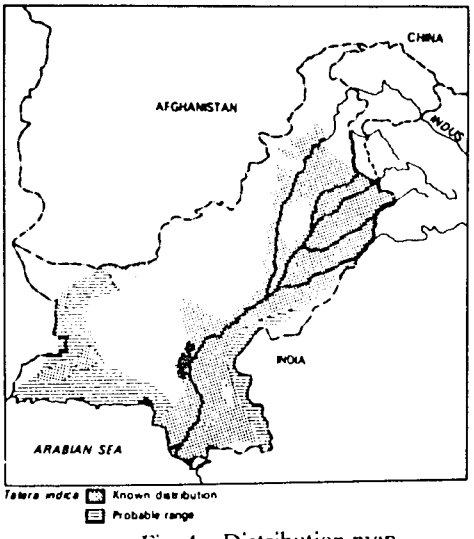


Fig. 4. Distribution map.

<u>Habitat</u>: It has been speculated that before the introduction of irrigation canals in the Punjab, the gerbil was confined largely to the sandy banks of rivers above the flood level, and that it has been able to reach the croplands in the doabs along irrigation canals. In the cultivated areas it inhabits mainly brushy sand mounds, alkaline wastes, fallow lands, and edges of irrigated fields.

<u>Habits</u>: The Indian gerbil lives in loose associations or colonies. It is an aggressive rodent and individuals live in separate burrows. Typically burrows are excavated in embankments or on uplands. The main entrance of a burrow system is always open and has fresh dirt in front with many foot prints on it.

Although the gerbil is often found in dry fields of rice and sugarcane, they cause very little damage to crops. However, its role as a pest in wheat fields is quite different. It occurs there in fairly good numbers, especially in fields adjacent to arid wastes and thorn scrub. It occurs in the wheat crop during all growth stages but attains maximum abundance during the flowering stage. The gerbil feeds on wheat seeds, tillers, ripening ears and ripened grains. In rainfed areas, it causes damage to a variety of crops.

The gerbil breeds throughout the year except during the colder months. In other parts of its range it may breed year round. Information about its reproductive parameters are given in Table 1.

Jungle cats, mongoose, jackals and foxes are among the important predators of the gerbil. The gerbil has a home range of about 2000 sq.m..

C. The Soft-Furred Field Rat (*Millardia meltada*)

Description: The soft-furred field rat is so-called because it has soft, silky fur. It is smaller than the roof rat but larger than the house mouse. The back is grey colored and the belly is white. The tail is sparsely haired and shows clearly visible annular rings (Fig. 5). The eyes are large and prominent and the naked ears also are rounded and prominent. Head and body length varies from 120 to 150 mm. The tail is over 80 percent of head and body length. Adult weight is about 60 g.

Fig. 5. The soft-furred field rat.

Distribution: Its distribution is roughly, similar to that of the bandicoot rat but it is absent from the N.W.F.P., most of Baluchistan and parts of southern Punjab (Fig. 6).

Habitat. It attains high abundance in irrigated or wet areas but occasionally is also found in dry scrub lands The soft-furred field rat avoids purely sandy areas, but certainly tolerates quite saline areas having predominantly halophytic type of vegetation. A couple of decades ago it was reported to be uncommon in the central Punjab. Today it is one of the common rats of the croplands. The soft-furred field rat lives in simple burrows usually located on bunds and at the edges of the fields. Burrow openings are often under bushes. In cultivated lands it destroys crops and is an important pest of all the three major crops, namely: wheat, sugarcane, and rice. In rice fields it feeds mainly on flowers, ripening earheads and ripe grains. Insects form a significant part of its diet. Sometimes rice is present in the diet of the rat long after the harvesting of the crop. The soft-furred rat is not known to hoard food in its burrows. Perhaps the rats steal from the grains stored in the bandicoot burrows or they glean them from the fields.

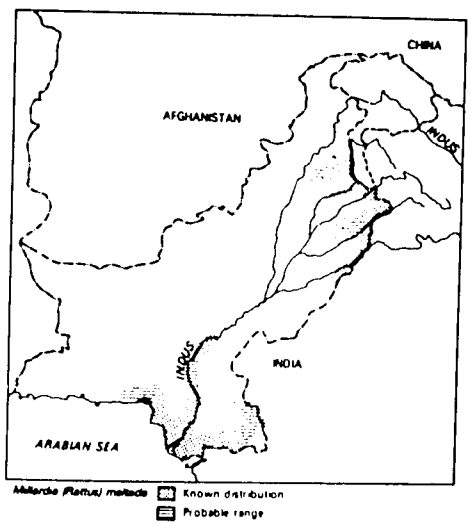


Fig. 6. Distribution map.

Habits: It is nocturnal in activity and spends the day concealed underground. It is considered a rather poor burrower, preferring to make use of natural crannies in loose stone walls and embankments, or even natural cracks in the soil. It is not particularly colonial. Two or three individuals may occupy burrows located in the same vicinity. *M. meltada* habitually builds a nest chamber in its underground burrow. The soft-furred field rat reaches sexual maturity quickly. This helps the rat in maintaining a high reproductive rate (see Table 1). It breeds year round, except in the winter months.

The home range of the rat varies from 790 to 2200 sq. m. The natural enemies of this rat are the same as that of the bandicoot rat.

D. House Mouse (*Mus musculus*)

<u>Description</u>: The house mouse is a relatively small rodent with conspicuous rounded semi-naked ears and slender semi-naked tail generally equal to or longer than the head and body length (Fig. 7). It has light, brownish-grey back and white belly. Head and body length ranges from 60 to 83 mm with the tail ranging from 62 to 89 mm. Adult mice weigh 16 to 21 g.

Fig. 7. House mouse.

<u>Distribution</u>: The house mouse occurs in all the four provinces throughout Pakistan, including the northern Himalayan regions, even in the remote mountain villages. In the north it extends into the mountain valleys of Hazara District, Chitral and Swat. It has been collected at such widely scattered localities as Pasni on the Mekran Coast and in the Naltar north of Gilgit, as well as Naran in the Kaghan valley (Fig. 8).

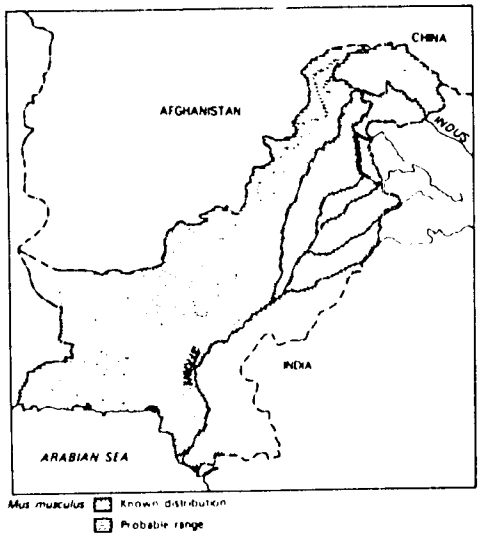


Fig. 8. Distribution map.

<u>Habitat</u>: It exploits both indoor as well as outdoor habitats. It lives in the croplands throughout the year and in fairly good numbers too. The burrows of the mouse are shallow and simple. Mostly they occur on the bunds or under bushes. During the harvesting season the mice are common under the harvested heaps of wheat and rice. The mice seem to feed on the grains only, causing damage mainly during the sowing and harvesting seasons. Insects form a good part of the diet of the mouse.

<u>Habits</u>: The house mouse is largely nocturnal. It is a good climber and inhabits the upper part of rooms and structures. More than one individual can utilize the same burrow system.

The house mouse is omnivorous in feeding habits. It can eat cooked rice, meat, soap and butter. In cropland it probably feeds mainly on seeds and vegetative matter. It is the most frequently encountered pest rodent in grain storage centres.

The house mouse has a high rate of reproduction. It could produce as many as 12 litters in a year (Table 1) and as such are a constant threat to stored foods in urban and rural areas, field crops and to grains in threshing yards.

The house mouse has many natural predators but the small Indian mongoose and the little spotted owlet seem to be the major ones.

E. Short-Tailed Mole Rat (*Nesokia indica*)

<u>Description</u>: This rat has a scaly tail, robust body, deep muzzle and relatively naked ears (Fig. 9). It can be distinguished from *Bandicota* by its relatively shorter tail which never exceeds 70% of the head and body length. The upper lip does not cover the base of gum and teeth. The body fur is softer than the fur of *B. bengalensis*. The color of the body varies from dark greyish brown to reddish brown.

The belly is greyish white. The head and body length ranges from 150 to 180 mm and the tail is 110-129 mm in range. Adult specimens vary in weight from 120 to 200 g.

Distribution: It has been found throughout Sind, Punjab and most parts of Baluchistan. It occurs around Bannu, Kohat, Mardan and Peshawar and probably extends into Swat and Chitral (Fig. 10).

Habitats: The mole rat is found throughout Pakistan where the soil is damp and light. Its presence is indicated by mounds of loose soil. In this respect it is similar to the bandicoot rat. The mole rat is distributed widely along irrigation canals and ditches from where it spreads into cultivated lands. The burrow system is generally complicated and long and may extend up to 25 m in length. It is entirely absent from sand-dunes. It prefers to burrow along water courses and bunds, and perforates embankments and canals, causing loss of irrigation water.

Fig. 9. Short-tailed mole rat.

The mole rat is not common in croplands except those which occur near river banks and near to sandy banks of irrigation canals. It damages cane roots and root crops from underground. However when rice or wheat are ready for harvest, it feeds on the surface and damages the crop.

Habits: *Nesokia indica* is more fossorial than *B. bengalensis*. The burrows are more extensive than any known rodents of similar size. Tunnels are quite close to the surface (15 cm).

The mole rat is herbivorous and feeds principally upon the roots and stems of grasses from inside the burrows. Since it rarely emerges on the surface of the soil, it is supposed that seed grains and fruits are an insignificant part of its diet. It does not make underground food stores.

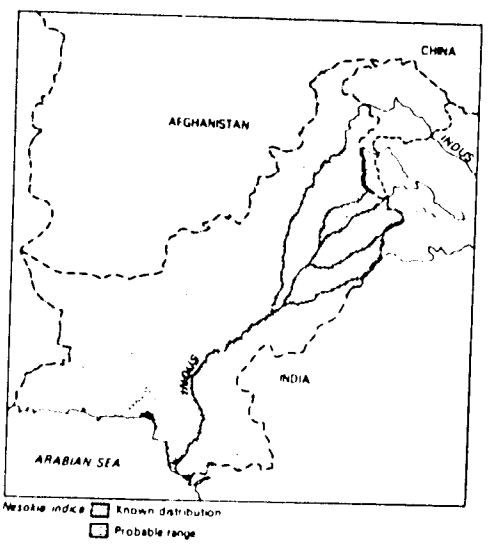


Fig. 10. Distribution map.

Breeding activity appears to continue throughout the year. Rate of pregnancy is 30%. Average litter size is 2.4 per female. Average number of litters produced per year is 6.4. The reproductive rate of the mole rat is low as compared to other field rats but its life span is greater.

Snakes and owls seem to be the important predators of the mole rat.

F. House Rat (*Rattus rattus*)

Description: The roof rat is a commensal of man and occurs almost throughout Pakistan. The roof rat is generally dark grey-brown with a white or creamy-grey belly. The tail is dark colored and nearly naked in appearance. The tail is one and one quarter-times as long as the body size. The muzzle of this rat is slender and pointed. Ears are prominent, large and naked (Fig. 11). The head and body of adults varies from 150-200 mm and tail upto 225 mm. Adults weigh from 140 to 220 g.

Distribution: It occurs in all the larger towns and villages throughout Baluchistan, Sind, Punjab and NWFP. It has also been trapped in Swat, Dir and Murree in the Himalayan regions (Fig. 12).

Habitat: It occurs in grain stores, food shops, poultry farms, and human dwellings. Many farm houses, too, have a population of house rats of their own. The house mouse and sometimes the Indian gerbil join the house rat in the farm houses. However, the house rats are strictly confined to farm house as they are only rarely found in the croplands surrounding them. It prefers to live in crevices, in the eaves of roofs, holes, and in stacks of bagged grain.

Fig. 11. House rat.

Habits: The house rat has a varied diet. Usually it feeds on stored grains as well as refuse and discarded garbage. It can eat all kinds of green vegetables, seeds, nuts, fruits, meat, insects and even leather and candle wax. In the coastal area of Pakistan it inflicts damage to coconut plantations, living and nesting in the crowns of the palm trees. Beside spoiling food and property, house rats present a health hazard. Rat fleas collected from this species are known to be vectors for such diseases as of bubonic plague and murine typhus.

Breeding takes place throughout the year. Spring and summer are the seasons of the maximum production. The average litter size in central Punjab is 6.2 and the annual production of young has been estimated as 65, that is, just the same as for the soft-furred field rat. The home range of the house rat may be as large as 400 sq. m. in area.

Rattus rattus

Fig. 12. Distribution map.

The chief enemies of the house rat are domestic cats, little spotted owlet and the small Indian mongoose.

G. Norway Rat (*Rattus norvegicus*)

Description: This is a large heavy bodied rat with blunt muzzle and small ears. It is distinguished from the roof rat as the tail is shorter than the head and body and it has smaller ears (Fig. 13). The body fur is course, dark brown on the upper surface and generally greyish on the belly. The tail is generally naked and scaly. Head and body length averages 229 mm (range 222-255 mm) with the tail length averaging 196 mm (range 190-220 mm). Adults weigh from 200 to 400 g. The female has 12 mammaries.

Distribution: The Norway rat has a very restricted distribution in Pakistan. It is found in Karachi city, particularly in the port and dock area. There are small populations in Pasni and Gawadar sea coasts. There is also a small population living in and around the Lahore railway station (Fig. 14).

Habitat: It is exclusively a commensal species in Pakistan. It is the most efficient burrower amongst the *Rattus* species in Pakistan. It excavates extensive tunnels under the foundations of buildings. It can also occupy the drains and underground sewers. The open refuse dump is also a favorite habitat for this species.

Habits: The Norway rat is an aggressive and bold rodent. It is quite agile and can climb fairly well. The Norway rat is a strong digger and prefers to live in underground burrows. Individuals within a certain territory recognize each other by smell and live in close association, which might be likened to a tribe. It is a serious pest in Karachi, particularly in destroying rice and wheat stocks being stored at the TPX produce yards. It is omnivorous and largely nocturnal in feeding activity.

In Karachi it has been found to breed throughout the year, producing on the average 7.4 young in a litter. Like the roof rat it is largely dependent on man for food and shelter.

Fig. 13. Norway rat.

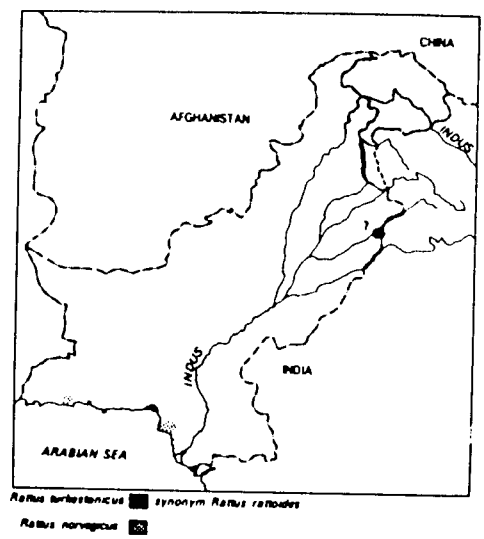


Fig. 14. Distribution map.

II. Desert Jird (*Meriones hurrianae*)

Description: The desert jird can easily be distinguished from the Indian gerbil by its much smaller ears and a creamy-colored but not white belly. The soles of the hind feet are hairy with a restricted naked patch around the region of the head (Fig. 15). Adults weigh 70 to 100 g. Head and body length averaging 125 mm (range 115-143 mm) with the tail averaging 132 mm (100-151 mm).

Distribution: It is found in the sand dune areas in the sea coast around Karachi and extends westwards into Mekran. It occurs in the barani areas as well as desert areas from NWFP through Punjab and Bolhari in Sind. It is not found in the rockier part of the Salt range and Himalayan foot hills (Fig. 16).

Habitat: It does not occur in rocky areas and seems to need fairly firm soil for burrowing. Its burrows are not found within well cultivated irrigated tracts but always in waste areas and non-cultivated patches such as road-sides, canal embankments and sand hills.

Habits. The desert jird is active during daylight. It is gregarious and live in colonies. Burrow openings are concentrated on hummocks around shrubs and sometimes in embankments on the edge of dry fields. In irrigated and scattered regions of Punjab, the jird is restricted to wastelands. During the summer season the jird is active in the early morning and evening.

The desert jird is considered to be one of the pests to rainfed wheat in Pakistan. Damage to wheat always appears as a patch of completely grazed wheat near the burrows on the edge of the field. It cuts young growing wheat and other crops and carries both stalks, leaves, and seed parts to store in its burrow.

It has been found in abundance around grain storage bini shells near Bahawalpur in Punjab and Bolhari in Sind. Its feeding territory seems to be within a radius of about 20 m only from the burrow, with a maximum range of 150 m. This desert jird can breed throughout the year but two peak periods are February- March and July-August. Gestation period is 28-30 days. Average litter size is 3-5 and females produce 3-4 litters per year.

The common predators of the desert jird are the desert fox, jungle cat, white-eyed buzzard and the rat snake.

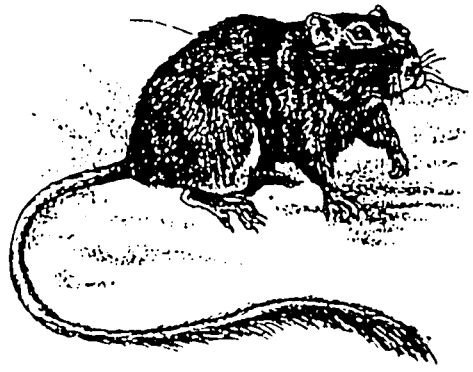


Fig. 15. Desert jird.

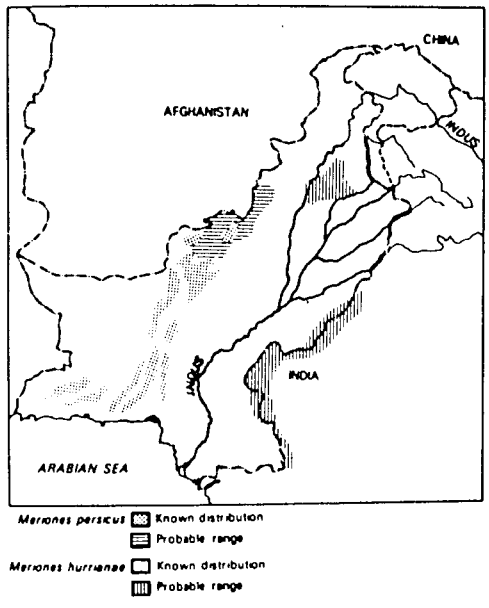


Fig. 16. Distribution map.

I. Libyan Jird (*Meriones libycus*)

<u>Description</u>: The body fur is long and silky, with the hairs averaging 13 to 15 mm in the dorsal area. The hair on the ventral surface is pure white and the terminal tail tuft is generally blacker than that of *M. hurrianae* (Fig. 17). Head and body length averages 113 mm (range 115 to 168 mm); tail 137 mm (range 125 to 162 mm). Adult body weight varies around 90 g.

<u>Distribution</u>: In Pakistan the Libyan jird occurs in western Baluchistan. It has been collected throughout Kharan and Kalat, around Dalbandin and Nushki and around Quetta upto Chaman. It seems to be rare in the northern mountainous part of Baluchistan (Fig. 18).

<u>Habitat</u>: It is confined to the valleys and low-lying areas, and it avoids steep mountain slopes. It is found upto 1680 m (5500 ft) and is typically associated with tamarisk studded sandy flood plains in Baluchistan and the edges of cultivation in the broader valleys.

<u>Habits</u>: Like *M. hurrianae*, it is diurnal and gregarious and lives in extensive colonies where its burrows are located in comparative close proximity. This species does not seal the entrance of its burrow. It feeds on various grass seeds and succulent fruits. In cultivation it often does

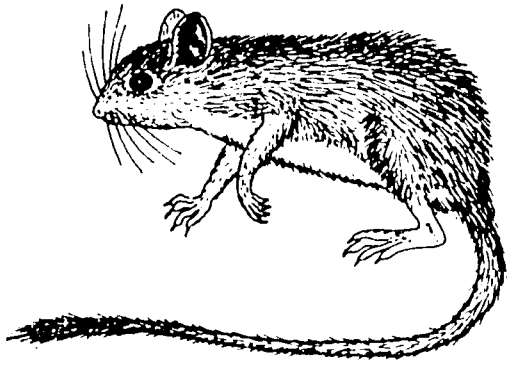


Fig. 17. Libyan jird.

considerable damage to tomato and potato crops. It hoards food in the burrow for consumption during the colder months.

Breeding activity is confined to the spring and autumn months. Average litter size appears to be three or four.

J. Northern Palm Squirrel (*Funambulus pennanti*)

<u>Description</u>: The squirrel has rounded ears, dark bright eyes and rather pointed muzzle. Fur of the head, neck, shoulder and outer limb surfaces is a grizzled pale grey. The dorsal body area is an olive-grey brown color divided by three conspicuous longitudinal cream colored stripes. The belly is creamy-grey and separated from the dark dorsal color by indistinct creamy-buff longitudinal stripes. The long sparse hairs of the tail are creamy or white at tip and base with a black middle band (Fig. 19). Head and body length varies from 130-165 mm while range of tail length is 120-160 mm. Adults weigh 100 to 150 g.

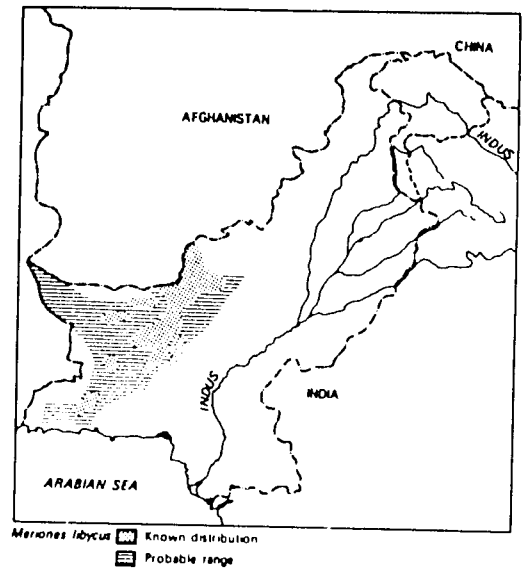


Fig. 18. Distribution map.

<u>Distribution</u>: The palm squirrel is widely distributed in Pakistan. It is found throughout the NWFP except in higher mountain regions. In Cholistan, Thal and Tharparkar, the squirrel inhabits wherever there is human habitations. It extends across southern Baluchistan in Mekran (Fig. 20). Salt Range is also occupied by *F. pennanti*.

Fig. 19. Northern palm squirrel.

<u>Habitat</u>: It is common in large cities, villages and semi-desert regions. Throughout the Indus Plain it is associated with *Acacia arabica* and *Albizzia lebbeck*. In the Mekran, date palms are the dominant vegetation type occupied by this squirrel.

<u>Habits</u>: *F. pennanti* is diurnal and arboreal. The night is spent sleeping inside a tree cavity or crevice in the wall of a building. Seeds and berries are its principal foods but it may supplement its diet with insects, eggs of birds, leaves and buds. It is often very destructive in vegetable gardens and orchards. It inflicts widespread damage to sprouting maize and wheat. Occasionally, the squirrel learns to feed on pulp of sugarcane and may cause considerable damage to cane crops growing near farm houses.

Fig. 20. Distribution map.

The squirrel breeds from April through September in central Punjab. But, in other parts of

its range it may breed throughout the year. It attains sexual maturity at the age of about 7 months and lives for about 18 months.

The mongoose, little spotted owlet, and cats are its main enemies.

K. Indian or Crested Porcupine (*Hystrix indica*)

Fig. 21. Indian or crested porcupine.

Description: A large rodent. The body is covered with quills with alternate deep brownish-black and white bands (Fig. 21). It has a long crest of bristles from the forehead to back of head. The tail is short and covered with short white quills. Measures between 46.0 and 71.5 cm in head and body length, with a tail of 10.6 cm. Adult body weight probably between 10 to 18 kg but specimens as large as 27 kg have been reported.

Distribution: The porcupine occurs over most of Pakistan, even into mountainous areas and juniper forests in Baluchistan as well as irrigated areas in Sind and Punjab (Fig. 22).

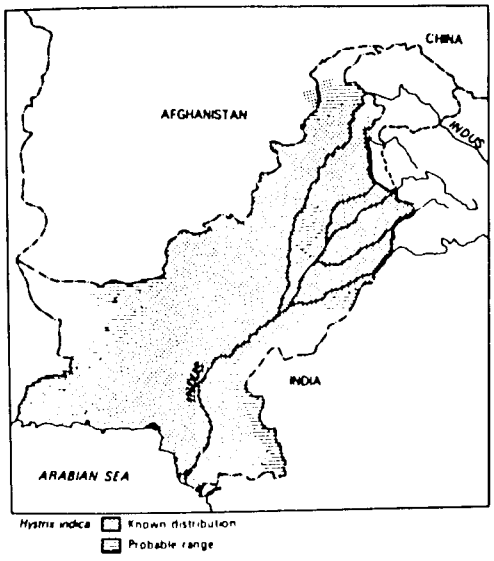


Fig. 22. Distribution map.

Habitat: It prefers rocky habitats, sandy soils and burrows into embankments along abandoned irrigation and drainage ditches. May be found in forested areas in irrigated tracts. It is more plentiful in areas with broken rocky hillsides and is much less common on alluvial plains. In canal irrigated croplands, creation of irrigated forest plantations and high embankments of drainage canals seem to have greatly fostered its spread and increase in the Punjab. These places provide the porcupine ideal denning sites.

Habits: Nocturnal and terrestrial. In rocky habitats inhabits caves or burrows usually dug between crevices. In sandy areas and embankments, digs long burrows that may extend 8 to 20 m, ending in a wide chamber. Normally lives in family groups, sharing the extensive burrow system. Burrows, if undisturbed, may be used continuously for many years.

The porcupine leaves its den soon after dusk and remains active till dawn. Its range of movement is extensive. It regularly visits the nearby crop fields and tree plantations. It is especially destructive to sweet potatoes, potatoes, beetroots, onions and carrots. It debarks and girdles trees, such as mango, apricot and orange and kills the seedlings of forest trees.

The porcupine is a slow breeder. It litters just once or at most twice in a year and a litter generally consists of 2 to 4 young. However, because of its large size, longer life, and larger home range it is a destructive and economically important pest. Furthermore, it is well protected against predators because of the protective cover of long quills.

L. The Murree Vole (*Hyperacrius wynnei*)

Description: The Murree vole is a small-sized, very dark- brown burrowing rodent with short velvety fur, long cylindrical body and well-developed blunt head with powerful protruding incisors. The tail is very short. It spends most of its lifetime underground and, as a consequence, has very tiny eyes and very small ears (Fig. 23). Head and body length averaging 115 mm (range 101-138 mm), the tail averaging 32 mm (range 24-39 mm). Adult weight varies from 42 to 60 g. The female always has six mammae.

Fig. 23. The Murree vole.

Distribution: It is abundant throughout the forest region in the Murree hills extending westwards through the lower forested regions of Hazara district (Shogran in the Kaghan valley) across the Indus to Lower Swat (Fig. 24).

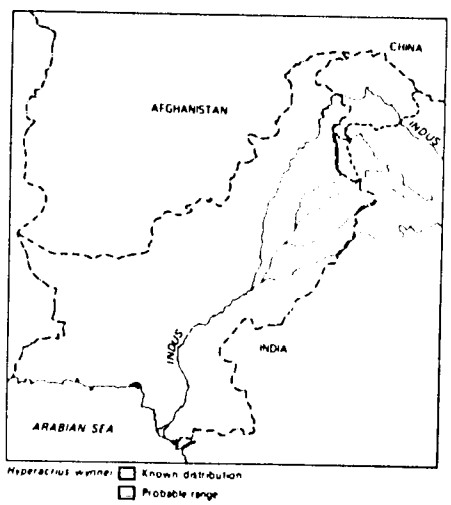


Fig. 24. Distribution map.

Habitat: This vole is associated with Himalayan moist temperate forest and is found from about 1850 m elevation upto 3050 m both within forest and open grassy slopes. It has been found at 2800 m elevation (Mukshpuri). It is typically adapted to live in silver fir and blue pine.

Habits: The Murree vole excavates an extensive network of comparatively shallow feeding tunnels. For breeding and sleeping much deeper tunnels are made which descend almost vertically into the ground.

It is a serious pest of apple orchards, as well as maize and potato crops grown at mountain elevations. It damages apple trees by gnawing the bark, either just below the soil surface, or in winter time, upto a few inches above the ground surface. It gnaws maize stalks, cutting them just at or below ground level.

Females probably produce two to three litters each summer. The litter size may be 2-3.

RODENT BIOLOGY AND BEHAVIOUR

By Abdul Rauf Khokhar

A. Reproduction and Growth

Rats and mice typically have high reproductive rates which balance their low survival rates. In most species, the reproductive rate is low in some months and high in others. Knowledge of this seasonal variation and a basic understanding of reproduction in rodents is important and is useful in planning control procedures.

The female reproductive system consists of vagina, uterus, ovaries and mammary glands. Externally, young females resemble young males since females have a structure (clitoris) homologous to the male penis and since the vaginal opening in sexually immature females is closed (imperforate) and not easily seen. The sex of young animals can be determined by noting the distance between the penis or clitoris and the anus. The distance is short 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 in the abdomen and not externally visible. 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 4 to 7 days. This period of receptivity is known as estrus. In most rats and mice and in pikas, the female may be receptive to copulation within a few hours after giving birth. This is called post-partum estrus. Normally in rats (*Rattus norvegicus*) the gestation period, or time from fertilization to birth of young, is 23 days; in mice it is 19 days; in pikas 30 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.

B. 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 (logistic growth curve, chapter 3).

C. 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 Pakistan, 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.

The example of *B. bengalensis* in rice fields of lower Sind can be cited to explain the pattern of seasonal changes in population density. Population density is low (one to five rats per hectare) from March through July. In July and August immigration from swampland into rice fields cause density to increase slightly. A great increase in reproductive rate (upto 5 young produced for each adult female in October) in the fall when the grain matures results in a great increase in density to about 50 rats per hectare. In November and December, after the rice harvest, many bandicoots leave the rice fields but those with well established home burrows remain and may produce a second or third litter. As the fields dry out and are grazed by cattle or ploughed for a winter crop, they become less suitable for bandicoots. Reproduction declines and emigration and mortality remain high resulting in a sharp decline in density in January and February. From March through July reproduction is almost zero. Since the few bandicoots remaining in the fields all have well established burrows, mortality is low. Density is low but stable through the winter and spring until the next rice season.

Nesokia indica, another rice field pest, differs greatly from this pattern. Like most fossorial rodents (burrow living), it has a small litter size (average 4.2 young per litter) but a high survival rate. The average life expectancy in *Nesokia* may be about 9 months compared to about 4 months in *Bandicota*. In populations of *Nesokia*, immigration and emigration are not as important as in populations of *Bandicota*. The home range in *Nesokia* is small. It does not move long distances even after crop harvest because it mainly feeds on underground tubers and rhizomes rather than the crop.

Millardia meltada, a third species of rice field pest, has a moderate litter size (average 5.6), probably a low survival rate, but longer breeding season (all the year except cold months) with a large percentage of adult females pregnant. The length of the breeding season has a great effect on the population density especially if it is long enough for females born early in the season to reach sexual maturity and have a litter before the end of the season.

Thus three different species (*Bandicota, Nesokia* and *Millardia*), all living in rice, have different patterns of population dynamics. Each pattern ensures the continued survival of populations of each species with its own unique mode of life.

D. Social, Feeding and Exploratory Behaviour

Behavioural studies may focus on the same aspects of biology as ecological studies but from a different point of view. For example, an animal behaviourist studying the preference of *Rattus rattus* for living in buildings will try to discover the mechanism for this preference. To what extent is the habitat preference influenced by the heredity of the animal or by its early experience? To what extent is the preference due to aggression or competition from other rodent species which live in the fields and thus may force *R. rattus* to live in buildings? Such studies allow us to understand better how one species might respond to reduction by control of other species.

Similarly information from other types of behavioural studies may be useful for control. For example, a study of the response of rodents to a new object or odour may help to find more attractive baits.

Males of Norway rats, rool rats and house mice have been found to be territorial under conditions of low to moderate population densities, defending burrows, runways or nest sites and a number of females living in association with them. Similarly, females at advanced stages of pregnancy or nursing young were also found to defend their nest and their immediate, surroundings.

In another study on Norway rats living in an outdoor enclosure, it was found that certain males dominated the most favourable places close to the food supply. These males established their territories near the source of food and also controlled burrows containing several females.

While conducting laboratory studies on the reproductive biology of *Bandicota bengalensis* in the Vertebrate Pest Control Laboratory, Karachi, the female bandicoot rat was found to resemble the Norway rat in defending the nest box and its surrounding. Even several days after the attainment of weaning stage by the young, the female did not allow the male (father) to come near the nest box containing the young. Conversely,, female *Nesokia indica* was found to be much more docile and did not show any excitement when its young were taken out of the nest box for observation. However, the mother did protect the young by plugging the hole of the nest box with straw and pieces of newspapers.

Different rodent species living in the same place may differ in their diet. For example, both *Millardia* and *Bandicota* mainly eat rice when the crop is near harvest. But when rice grain is absent, *Millardia* depends mostly on insects and grass seeds while *Bandicota* eats almost exclusively the rice stems and plant roots. Such a difference in feeding behaviour when food supply is low prevents severe interspecific competition.

Wild rats and mice display a strong exploratory drive within range of their home. They constantly explore known and new aspects of their environment; in a short time they come to know all features thoroughly and are able to move to shelter immediately danger threatens. During exploration they sniff and investigate objects within their range, tasting and sampling any foods or liquids that are found. The end result of this exploratory behaviour is to make them familiar with a wide variety of situations in their immediate environment.

In exploring their environment, rats and mice go through a learning process. The details of pathways, obstacles, hiding places, and the locations of food and water are memorized and the muscular movements necessary, for example, to move down a runway and to take refuge, are also learned. This is known as orientation using a kinesthetic sense. This behavioural trait is easily demonstrated by covering an opening that rats or mice have been used to entering. When disturbed,

they will repeatedly attempt to enter the opening, which their kinesthetic sense has informed them should be there. Such detailed familiarity with the living space, the location of food and water, known runways, burrows and other places of concealment, greatly aids in individual survival.

Inquisitive exploratory behaviour would quickly lead rodents into traps or result in their ingestion of poison bait if it was not inhibited in some manner. Another behaviour pattern, opposite to exploratory activity, serves to protect them from their own curiosity. Thus, Norway rats, roof rats, and lesser bandicoot rats will quickly detect but initially avoid any strange objects that are encountered in a familiar environment. This behaviour, which has been called "new object reaction" or "neophobia", is most easily seen in the case of rats living in an area with established runways. The use of a runway can be prevented, sometimes for days, by simply placing upon it a harmless but unfamiliar item, such as a block of wood. Other objects, such as a bait container or trap can produce the same effect. "New object reaction" is less evident in mice, which become accustomed to traps and strange food within a relatively short time.

METHODS OF RODENT POPULATION ESTIMATION

By Abdul Aziz Khan, Abdul Rauf Khokhar, Iftikhar Hussain and Joe E. Brooks

Rodent populations are studied and estimated with techniques which are biologically and statistically acceptable. Population estimates are helpful in calculating the extent of grain losses to rodents or in following the seasonal changes that occur in field crops during several growing cycles. Some methods give information on the distribution, size and species composition of the population while others give only indirect measures, such as activity measures. All have their uses, however, and several methods, both direct enumeration and indirect estimations, will be outlined.

A. Visual or Preliminary Survey Inside Structures

A preliminary survey of rodent populations inside structures (poultry houses, grain shops, godowns) will include:

1. Sounds: Gnawing, clawing, climbing, squeaks and noises etc.

2. Droppings: Found along runways, shelters and other places where rats frequent.

3. Urine: Wet or dry.

4. Smudge marks: May be found on pipes and roof beams in poultry farms particularly.

5. Runways: All walls, all fences, under bushes and buildings.

6. Tracks: Foot prints or tail marks on dusty surface or on spillage commodity, like flour. Use tracking patches (flour, chalk or talcum powder) to record tracks overnight.

7. Gnawing: Wood chips around baseboards, doors, basement, windows, frames, store materials provide evidence of rodent damage.

8. Nest and food caches.

9. Pet excitement: Cats and dogs show peculiar behaviour towards rats.

10. Rat odours: A peculiar smell indicates presence of rats or mice.

11. An experienced rat control worker can estimate low, medium and high population by seeing rat signs, burrows and food caches.

    a) Rat free or low infestation: No signs as mentioned above or few foot prints.
    b) Medium population: Old droppings, gnawing common,no rats seen in day time. There may be 10 or more rats in such situations.
    c) High population: Fresh droppings, tracks are common, gnawing present, one or more rats seen at day light or night. here may be 50 or more rats.

12. To record the above information you need the following equipment; a) Electric flashlight/ torch, (b) Tracking powder (c) Clipboard and record sheets

B. Trapping Methods

Both statistically and biologically reliable data can be obtained from trapping methods.

1. Trapping to Extinction

Complete trapping will give the actual population present in an area. This procedure is used in small godowns (500 tons capacity) or small poultry farms. The objective is to trap out all the rats possible and in a period not exceeding 21 days. This can be achieved both by live or kill trapping. Trapping is monitored by the foot prints on tracking patches. When the tracks are absent, all rodents have been trapped. It may sometimes happen that though the vast majority of rodents are trapped, a few reluctant individuals avoid the traps. The size and species composition of this residual population, provided it is very small, can often be estimated from the frequency of foot prints on the track patches.

2. Capture-Mark-Release (CMR) Method

A large number of studies has used a method based upon the recapture of marked individuals. Timewise this method is divided into two phases; first a sample of animals is caught alive, marked and released back into the original population. In the second phase, animals are again captured from the same population and the previously marked animals are recorded along with the new ones that are trapped. The method itself depends upon a very simple ratio. The population (P) is related to the number marked and released (M) in the same way as the total caught (n) at a subsequent time is related to the number of marked animals recaptured (m), or:

$$\frac{P}{M} = \frac{n}{m}, \text{ whence } P = \frac{Mn}{m}$$

As an example, assume we captured 100 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 90 rats (n) out of which 30 were marked (m). The population is estimated as:

$$P = \frac{100 \times 90}{30} = 300 \text{ rats}$$

There were an estimated 300 rats in the original population in the grain shops. The confidence limits at the 95% level may be calculated from the standard error:

$$S.E. = \sqrt{\frac{M^2 n(n-m)}{m^3}}$$

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:

$$S.E. \doteq \sqrt{\frac{(100^2 \times 90)(90-30)}{100^3}} = 7.4 \times 2 = 14.8 \text{ (rounded to 15)}$$

Upper limits = 300 + 15 = 315
Lower limits = 300 - 15 = 285

Population estimates by this method will be based on two important assumptions:

a) No significant change in population takes place during the period of study.
b) The chance of capturing a rodent in the second phase is independent of whether or not it is marked.

For trapping purposes the following equipn.ent is needed:

a) 100 live traps (rat size)
b) 100 live traps (mouse size)
c) Cloth bag to hold live rodents for marking
d) 2 pairs of dissecting scissors
e) Spring balance (100 x 1 g)
f) Spring balance (500 x 5 g)
g) Marker
h) Trap baits

Animals can be marked by clipping one or more toes or by cutting notches in the ears. Toe clipping relies on using the forefoot digits for numbers 20, 30, etc. through 80 (each fore- foot has 4 toes) and using the hindfoot digits for numbers 1 through 10 (each foot has 5 digits). Thus 99 numbers are possible (Fig. 1). The ears can be clipped in a pattern representing the numbers 1,2,4 and 7, thus any number upto 9 can easily be clipped in one ear with only 2 notches. The other ear could be notched for numbers 10 through 90, thus giving 99 numbers.

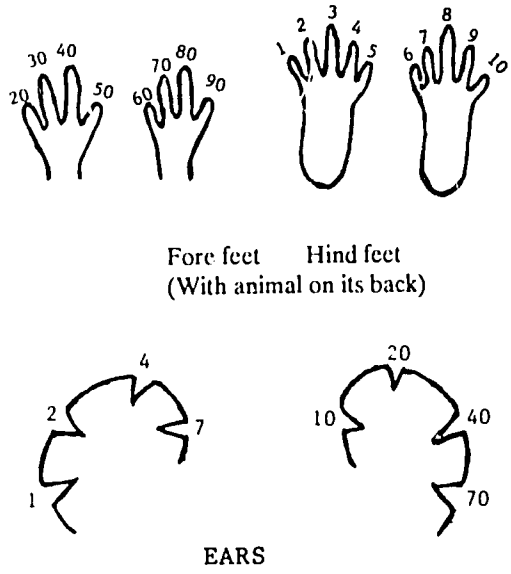


Fig. 1. Methods of marking animals.

CMR methods are laborious and time consuming. Moreover, shopkeepers or householders are not pleased to have the rats captured and then again released into their premises. For these reasons, these methods are rarely used in such premises. For outdoor field studies, however, these methods are quite suitable.

3. <u>Trapline Method</u>

It is preferable to use a transect method in setting traps in the field. The traps are set in pairs. Such pairs are placed about 10 paces apart in a straight line and about 2-3 meters inside the crop from the edge. This allows two pairs of traps to fall within the home ranges covered by the line. If one rat is caught a second trap remains nearby to catch another animal. A buttered "chapatti" should be used which is attractive to a wide variety of rodents. Traps should be placed carefully upon flat and even ground. This is because even small animals do not like to step on something that tips or moves when touched. The relative abundance of animals is estimated through trapping success.

$$\% \text{ trap success} = \frac{\text{Number of animals caught}}{\text{Total trap nights}} \times 100$$

For example in a trapline of 200 traps set for 3 successive nights and catching 31 bandicoots, the trap success for the field sampled would be:

$$\frac{31}{3 \times 200 \text{ traps}} \times \frac{100}{1} = 5.16\%$$

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.

4. Regression of Daily Captures on Cumulative Captures

When removal trapping is carried out for six to 10 nights, it is possible to estimate the rat population from the daily decline in the number of animals captured. If the number caught each day is plotted against the number previously caught, then a straight line can be fitted by linear regression using the method of least squares. The point where the line crosses the abscissa gives the population estimate. As an example, suppose we capture the following number of rats in six nights:

Number Caught each Day	Cumulative Number Captured
59	0
56	59
42	115
39	157
26	196
27	222

When these are graphed and the regression line fitted, we get the example as shown in Fig. 2. Altogether, 249 rats were captured in six nights, leading to an estimate of 355 rats in the total population. This method can be used as a second population estimate along with the CIR method (below).

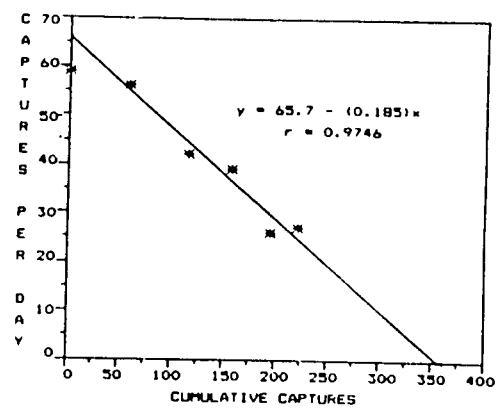


Fig. 2. Estimated rat population based upon decline in captures per day.

5. Change-in-Ratio (CIR) Method

More popular methods are those that remove the animals from the grain shops or houses. A method has been used that measures activity before and after trap removal of rats. This has been called the change-in-ratio (CIR) method because some attribute of the population (activity) has been changed by removal of part of the population. We have used this method to estimate the number of rats in farm houses and in grain shops. Activity before and after trapping is measured with inked or chalked tracking tiles (15 x 15 cm). These are placed for one night in all areas where rats could be expected to be moving around at night. Following the placement of tiles, rats are trapped for six to 10 nights to remove most of the population. Tiles are again set for one night to record the reduction in activity that the removal of a proportion of the population has created. The equation for calculation of the original rat population is:

$$\frac{T_1 - T_2}{n} = \frac{T_1}{P_1} = \frac{T_2}{P_2}$$

where T_1 is the proportion of tiles scored positive (with rat footprints) before removal trapping; T_2 is the proportion positive after removal trapping and n is the number of rats removed. The equation is solved for P_1, the original rat population. As an example, say the proportion of tiles positive before trapping was 0.80 (80 positive out of 100 set), and was 0.20 after removal trapping. We captured 120 rats, therefore:

$$P_1 = \frac{T_1 \times n}{T_1 - T_2} = \frac{0.8 \times 120}{0.8 - 0.2} = \frac{96}{0.6} = 160$$

The original rat population estimate was 160 animals. The method is simple, easy to run (takes only eight to 12 nights of tracking tiles and trapping) and pleases the shopkeeper or householder because most of the rats are removed from their premises. One disadvantage to this method is there is no way to calculate the confidence limits of the population estimate.

C. Indirect Methods

1. Food Consumption

One indirect method of population estimation is to use the amount of food baits consumed by a rat population over a period of up to 10 days. The method relies up the habit of rats to switch most of their nightly feeding over to a palatable, freely available food placed in abundance in their environment. This may be difficult in grain shops but has been done in some cases in godowns. In godowns where rice is stored, for example, bait containers with wheat mixed with 2% sugar and 2% oil will be utilized in preference to the rats normal diet of rice. The switch over takes up to 10 days, however, for all rats must find the new food baits and begin to do most of their feeding at the new bait sites. Generally, the consumption starts low but rises rapidly over the next three to four days (Fig. 3). However, baiting should be continued until consumption reaches a peak. The amounts consumed the last two to three days are averaged. This total is divided by the average daily consumption of wheat or other grain baits by the rodent species concerned. This gives a minimum estimate of the population since usually the animals continue to feed somewhat on their regular diet and some animals never do feed at the bait sites. A large number of bait sites must be used together with enough bait that the total amount at any one site is not entirely consumed overnight. The method is unreliable when more than one rodent species is present, since the proportion of consumption attributable to each is not known.

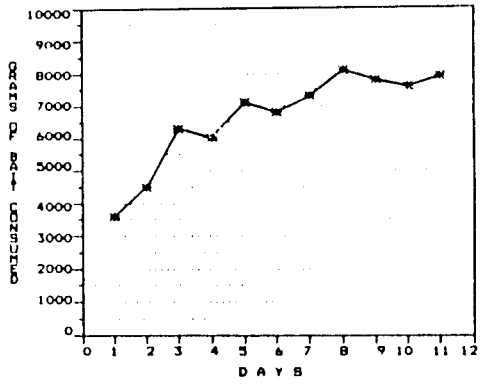


Fig. 3. Typical census bait consumption curve.

2. Tracking Patches and Tracking Tiles

Several indices of relative abundance can be used to estimate population changes from month to month or year to year. The activity index at tracking tiles can be used to measure relative population

activity (Table 1). Set approximately the same number of tiles for one or two nights each month. Score the number positive out of the total set.

Table 1: Index of Abundance: Activity at Tracking Tiles by Month and Catch/Unit Effort

Month	No. of Tiles Positive (%)	No. Trap-nights	No. Animals Captured	Captures Per Trapnight
Oct.	41.7	349	74	0.212
Nov.	50.0	468	74	0.158
Dec.	50.0	480	78	0.162
Jan.	33.3	576	80	0.139
Feb.	27.8	576	52	0.090
Mar.	27.8	576	24	0.042
Apr.	36.1	574	43	0.075
May	34.7	576	34	0.059
Jun.	25.0	576	46	0.080
Jul.	30.6	576	57	0.099
Aug.	32.3	576	61	0.106
Sep.	35.0	576	64	0.111

Similarly, setting an equal number of traps each month in a fixed number of grain shops or houses will give a catch/unit effort index or captures/trapnight (one trapnight means one trap set for one night; 100 traps set means 100 trapnights). Remember not to trap the same premises each month since the trapping will change the animal abundance.

Notice that the population abundance as measured by index of activity at tracking tiles was at a peak in November and December and then declined until reaching a low in June. Catch per unit effort, however, indicated a peak in abundance in October, declining slowly through January, and reaching lows in March and May. Overall there is reasonable agreement in the two indices in that population activity and numbers were high in October through January, lowest in February through June, and were increasing again in July through September.

3. Use of Tracking Patches and Food Intake at Bait Sites

Tracking patches are an indirect method of measuring rodent population using an activity index of prints on the track patches laid along the walls, beside the doors or across their runways. These patches of the size of 15 x 35 x 0.3 cm are laid using Fuller's earth, China clay, fertilizer dust, talc powder, gypsum etc. Patches with foot prints are recorded as positive.

There is another indirect method for estimating rodent numbers, i.e., food consumption data at least for 3 nights. Assuming that any rat or mouse species eats 10% of its body weight, the total rats/mice present in the area can be determined. Alternately, the eaten bait points are recorded and calculated and represented as follows:

$$\text{Percent rodent activity (track patches or food intake)} = \frac{\text{No. positive patches or food intake points}}{\text{Total No. of patches laid/food points}} \times 100$$

These two indirect methods are highly practical and useful in evaluating and control materials and methods and monitoring control programmes.

DAMAGE PATTERNS OF RODENTS AND DAMAGE ASSESSMENT METHODS: PREHARVEST CROPS

By Abdul Rauf Khokhar

Pakistan, like many countries of the world, suffers serious losses due to rodent depredations to its agricultural crops. Three major crops, viz., wheat, rice and sugarcane remain vulnerable to rodent attack at every stage of their development, right from sowing to the harvest stage.

Generally, losses at the initial stage of crop development are not so severe due to the fact that the damaged plants which are attacked by the rodents regenerate their parts. However, the damage done at the advanced stage of crop development seriously decreases yield.

In most of the countries where rodent problems have been studied, generally, one species of rodent is involved in causing the damage to various crops. But in India and Pakistan the rodents involved are a complex of several species. These species are *Bandicota bengalensis, Millardia meltada, Nesokia indica, Mus* spp., *Tatera indica, Meriones hurrianae* and *M. libycus*. As these species belong to different genera, their pattern of damage to the crops is also different.

A. DAMAGE PATTERN

1. Rice

Four species largely responsible for damage in rice crops are the lesser bandicoot rat (*B. bengalensis*), soft-furred field rat (*M. meltada*), the short-tailed mole rat (*N. indica*) and the house mouse (*Mus musculus*).

Sometimes a fifth species, the Indian gerbil (*T. indica*) has also been found to infest rice crop but only when the fields are dry and ready to harvest. They are never extremely abundant, however.

a) Lesser Bandicoot Rat (*Bandicota bengalensis*)

In flooded rice fields, bandicoot rats make their burrows in the bunds between the fields and swim into the paddy and eat succulent rice stems and developing seeds. When the rice fields become dry before harvest, bandicoots either extend their burrows from the bunds to inside the fields or abandon the bunds and make fresh burrows inside the field. The presence of large open holes with occasional earth mounds and distinct well-marked runways are the characteristic signs of *Bandicota* on the bunds and inside the field. In severe cases the whole field could be found littered with *Bandicota* burrows. They do the greatest damage in the final weeks before harvest, when they store large quantities of grain in their burrows. We have found up to 100 kilograms of rice per hectare stored in bandicoots burrows or one-tenth of the total production of the field. Bandicoots are capable of inflicting this amount of damage in less than a few weeks time.

After harvest, bandicoots usually continue to live in the fields, feeding on their underground stores and on spilled grain left behind by the harvesters.

If irrigation water is not available year round, bandicoots live through the dry season in low wet areas. There they feed on the tuberous roots of the sedge (*Scirpus maritimus*) which is a common weed in wet places and other weeds when no crop is available. When crops are again planted, they can move great distances to take advantage of this new food supply.

b) **Soft-Furred Field Rat** (*Millardia meltada*)

These rats are not strong burrowers and often live in cracks in the soil or in the spaces between the clods of dry earth usually left after the ploughing. They can be abundant in fields but leave little sign (burrows and runways) and therefore are often overlooked.

The abundance of *Millardia* in rice fields (at all stages of growth of the crop) remains relatively low and does not undergo rapid changes like that of *Bandicota*. Like bandicoots, they depend mainly on rice grain when the crop is at harvest stage. But before the panicles set grain, they feed on insects and grass seeds, unlike bandicoots, which cut the rice tillers from the bottom and eat the sweet pulpy portion of the stem. *Millardia* continues feeding on rice grains even long after the harvesting of the crop. These grains in the diet of *Millardia* are believed to be gathered through gleaning from the ground.

c) **Short-Tailed Mole Rat** (*Nesokia indica*)

Their presence in fields is indicated by mounds of loose soil, often along water courses and bunds. Their burrow entrances are usually covered by these mounds of soil. Plugs of loose soil are also found along the interior of the burrows. These burrows are long and more branched as compared with those of *Bandicota*.

The damage caused by *Nesokia* is often underground as they rarely come above the ground and mainly feed on the tuberous roots and rhizomes from inside the burrows. They do, however, come out from the underground burrows to feed on the rice grain as harvest nears.

d) **House Mouse** (*Mus musculus*)

Mice are pests largely because of the disease they carry and the likelihood that their presence will contaminate human food stocks. They are plentiful in rice fields. They are delicate and fussy feeders and in terms of the actual amount of grain consumed they are not as serious a pest as any of the rats.

2. <u>Wheat</u>

Like rice, wheat is also susceptible to rodent attack from the time of sowing till harvest and post-harvest stage. The main rodent species inhabiting wheat fields in Pakistan are represented (in order of severity) by *B. bengalensis, M. meltada, T. indica, N. indica, Meriones hurrianae* and *M. libycus*. The first four of these species cause extensive losses to irrigated wheat fields while the remaining two, along with *B. bengalensis* and *T. indica*, are the main rodent pests which inflict serious losses to wheat in the rainfed areas. *M. musculus*, very commonly found both in irrigated as well as the rainfed areas, is not considered a serious pest of wheat.

a) **Lesser Bandicoot Rat** (*B. bengalensis*)

B. bengalensis causes serious losses to the wheat crop in Thatta, Badin, Hyderabad and parts of Tharparkar in Sind; Faisalabad, Sheikhupura, Gujranwala, Sialkot and Rawalpindi in Punjab; and Hazara, Mardan, Peshawar, Malakand and Kurram in the NWFP. They may also spread and cause damage to wheat crops in the neighbouring districts during some years.

After showing a sharp decline in their density in the harvested and ploughed rice fields, bandicoots again start showing up in the next crop, which is mainly wheat in Pakistan. The response of this species in wheat fields is almost similar to that in rice crop. That is their numbers gradually increase as the wheat crop matures till they out number the other species. Bandicoot rats

begin to damage the wheat crop right from sowing and their damage reaches its peak (like in rice crop) at the harvesting stage. Bandicoots store ripe ears of wheat in their burrows.

b) **Soft-furred Field Rat (*M. meltada*)**

This species is known to attain maximum abundance when the wheat crop is at flowering and maturation stages. It is reported to become scarce during the ripening and mature stage of the crop. In one of the studies in central Punjab the population of this rodent remained unaffected in the harvested wheat crop (bare of any vegetational cover) even after ploughing of the fields. The presence of its fecal pellets in between the big clods of soil indicated that this species can live in between these clods of dry soil. *Millardia* is a serious pest in wheat crop, particularly at ear-ripening stage.

c) **Indian Gerbil (*T. indica*)**

The Indian gerbil digs deep burrows in the dry wheat fields and the burrows are always open. They never make their burrows in the frequently irrigated places. They do not cause damage of much significance to wheat crop in the rainfed areas. They are present in the wheat crop during all stages of growth but attain maximum density at the flowering stage. When the fields are wet they burrow in the bunds. The rats feed on the seeds, tillers, milky ears and the ripened grains. Threshing floors are the usual sites (after the wheat harvest) of *Tatera* burrows. They feed on the grain left on the grounds during or after the harvest operation.

d) **Short-tailed Mole Rat (*N. indica*)**

The behaviour of *N. indica* in wheat fields is similar to that described for rice fields.

e) **Jirds (*Meriones* spp.)**

The wheat crop in the rainfed areas of Pakistan suffers heavy damage due to attack of *Meriones* spp. The wheat crop in Baluchistan is attacked by *M. libycus* at every stage of crop development. *M. hurrianae*, however, is the principal pest species in the rainfed wheat of desert areas of the NWFP, through Punjab, Sind and along the Mekran coast. These are gregarious rodents which live in colonies. Their burrow openings are wide and conspicuous. They cut young growing wheat and carry both stalks, leaves and seed parts to store in their underground burrows.

M. hurrianae inflicts damage to wheat crop mainly near the burrow. Their damage is patchy in form. However the damage done by *M. libycus* is mainly confined to the margins of the wheat fields.

3. <u>Sugarcane</u>

Sugarcane differs from rice and wheat in two important respects. First, it provides cover to the rodents for a longer period (10-16 months) and hence is especially more susceptible to rodent attack. Second, cane is not nutritious enough to keep rodents in good health. Wherever sugarcane is grown, it suffers from rodent attack and in some parts of the world where this problem is studied there is only one species, *Rattus rattus*, involved in damaging the crop. In Pakistan and India, however, the species doing damage to sugarcane belong to at least five genera, viz., *Bandicota*, *Millardia*, *Nesokia*, *Mus* and *Tatera*.

Of these species, *Bandicota* is the most destructive. Most of the damage to cane crop is done during the months of December, January and February. These are the months when sucrose contents are high in the cane.

B. Estimating Crop Damage

Estimates of the amount of damage caused by mammal pests are valuable for planning control programmes. However, accurate estimates are difficult to make. The single most important rule in making damage estimates is: quantify your observations. To quantify usually involves counting. Merely inspecting a field and recording a general impression, such as "damage was moderate" is of little value.

Damage estimates in most situations are best made by walking a line (transect) through the centre of the field, stopping at fixed intervals and counting the number of cut and uncut stems. In rice, stems occur in clumps or hills and all the tillers in each hill can be counted at each stopping point.

Care must be taken to examine rice and sugarcane stems since in these crops rats may gnaw half of the stem leaving the stem standing and apparently undamaged when viewed from the other side. *Nesokia indica* may cut sugarcane stalks from below ground so that the stalk appears uncut above ground. Usually there are mounds of soil thrown up by the rat nearby and the cut stalk is dried out. When such a stalk is pulled, it comes out easily.

The transect method is suitable for estimates of damage that is spread randomly through the field. Damage due to *Meriones* in wheat or pigs and porcupines in sugarcane tends to be clumped in a single part of the field. *Meriones* eat all the wheat close to their burrow leaving other parts of the wheat field untouched. Pigs and porcupines usually feed from the centre of the field destroying virtually all the crop in a small area.

1. Wheat Damage Assessment

To estimate damage to wheat tillers, the following method is used:

a) Make a random selection of the fields to be sampled.

b) Sample the wheat fields using a square wooden quadrat of suitable size (either 50 x 50 cm or 1 x 1 meter). Throw the frame a minimum of 10 times while walking a predetermined line (transect) across the field. The field diagonal could be chosen or several transects across the width of the field can be used.

c) Count the total number of tillers and the number of tillers cut by rodents inside the wooden quadrat. Adjust the number of quadrat samples for the field size, using 10 samples as the minimum. For very large fields, upto 20 samples should be taken.

d) Express damage as:

$$\frac{\text{damaged tillers}}{\text{total tillers counted}} \times 100 = \%\ \text{damaged tillers}$$

2. Rice Damage Assessment

To estimate damage to rice, the following methods can be used:

a) Make a random selection of the rice fields to be sampled.

b) Using the field diagonal, take 25 counts at intervals that will allow the total counts to be taken within the field (i.e., if diagonal is about 50 m, take counts every 2 m).

c) At each point to be counted, examine the hill (rice plant with several tillers) nearest the observer's right foot. Record the hill as damaged or not. In addition, record total number of tillers and the number of tillers cut by rodents in each damaged hill.

d) Express damage as:

$$\frac{\text{damaged hills}}{\text{total hills counted}} \times 100 = \%\ \text{damaged hills}$$

$$\frac{\text{damaged tillers}}{\text{total tillers counted}} \times 100 = \%\ \text{damaged tillers}$$

Another method, used in the Philippines in transplanted rice, is to randomly select the rows to be sampled, and then randomly select the hills along each row to be examined. As before, the damage is recorded to both hills and to number of tillers, counting the total of each. Usually, 100 hills are counted in each field.

3. Sugarcane Damage Assessment

Rats damage both the roots (short-tailed mole rats mainly) and the portion of the stalk internodes, usually near the base of the cane. This means that individual stalks should be carefully examined to find both kinds of damage. Damage surveys at harvest tend to underestimate stalk mortality because stalks with severed roots which decompose would not be seen. Some stalks with cut roots do remain standing and could be detected at harvest. Rodent damage does not correlate directly with a decrease in sugar yield, because many plants, though partially damaged, do produce some sugar content at harvest.

Rodent damage to sugarcane can be estimated as follows:

a) Make a random selection of the fields to be sampled.

b) Select line transects to cross the fields. Sample at points on these lines at roughly every 8 to 10 m.

c) At each point, select the 10 canes nearest to the sampling point and examine each closely for signs of rodent damage (roots and internodes). Record the number of internodes damaged on each stalk and whether the roots were damaged.

d) Continue sampling in each field until at least 10 sampling points are taken for each acre of field (25 per hectare).

e) The sampling line transects should be drawn so that both the peripheral and the central parts of the field are sampled.

f) Damage is expressed as:

Total number of canes examined
No. of canes with damaged roots
No. of canes with damaged internodes
No. of canes with both internode and root damage
No. of canes with damage to 2 internodes upto half of the stalk
No. of canes with more than half the stalk damaged
Compute the percent damaged in each of the above categories.

DAMAGE ASSESSMENT AT POST-HARVEST LEVEL

by Joe E. Brooks and Ejaz Ahmad

Wheat production is concentrated in Punjab and Sind and only small quantities are grown in NWFP and Baluchistan. Wheat is procured during the months of April to August and it is moved to storage sites. Punjab has the greatest storage capacity, followed by Sind, NWFP and Baluchistan. The storage facilities are of various different sizes and designs. The predominant form is the house-type godown. Other designs include hemispherical shells, called bini shells, bins of concrete and bricks, and concrete and steel silos. In some areas grain is stacked in the open covered by tarpaulin sheets. Wheat is stored in storage sites from 2 to 12 months.

The usual vertebrate pests that cause damage and losses of stored grains are rodents and birds. The common rodent pests are roof rats (*Rattus rattus*) and house mice (*Mus musculus*). Other rodent species that may enter grain storage structures in Pakistan and consume and contaminate stored grains are the striped squirrel (*Funambulus pennanti*), desert jird or sand rat (*Meriones hurrianae*) and the Indian gerbil (*Tatera indica*). The major bird pest species found around grain storage are house sparrows (*Passer domesticus*) and domestic or wild rock pigeon (*Columba livia*). House sparrows can nest inside and outside the godown structures and fly in through open doors and unscreened windows. Pigeons rarely enter the structure, but are common outdoors, where they feed upon the spilled grain.

Rodent damage to stored food can occur in many ways. The animals not only directly consume the grains but also contaminate much more with their droppings, urine and hair. They also chew holes in bags which results in spillage which can become contaminated with rodent urine and droppings. In provincial grain storage centres the losses are very low i.e. less than 0.5% because of regular use of fumigants.

A. Damage Assessment in Godowns (Provincial and PASSCO)

In damage assessment methods at post-harvest level we will discuss only damage at storage level and in-field storage before threshing. To estimate storage losses due to vertebrate pests in public sector storage facilities, a survey of these sites was done during the period of January to June 1986 throughout Pakistan.

During this survey, sites were selected randomly and these sites were inspected. A survey form was used to record the observations and data collected (Appendix I).

The general procedure used was to interview the person incharge to obtain the details of staff, operations, structural capacity and age. After collection of the information, a physical examination of several godown structures, looking for structural defects, grain quality, structure condition, and evidence of vertebrate pest infestations. The degree of infestation was determined from visible evidence, such as live or dead animals, fecal droppings, burrows, bag damage, etc. The definitions used to categorize grain quality, structure condition, structural defects and severity of rodent and bird infestations are given below:

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1. **Grain Quality**

Excellent - Grain without insect damage, no impurities or seeds, and no broken grains.

Good - Grain without insect damage, mixed with some small amount of impurities or seeds, a few broken grains.

Fair - Slight insect damage, mixed with impurities and/or seeds, obvious broken grains, some rodent or bird fecal droppings.

Poor - Obvious insect damage, mixed with impurities and/or seeds, many broken grains, many rodent or bird droppings, moldiness.

2. **Structure Condition** (as judged from appearance on outside observation)

Good - No obvious defects visible.

Fair - Few defects visible, may or may not need repair.

Poor - Many obvious defects, in need of repair.

3. **Structural Defects**

Doors - Marked as defective if they allowed a gap large enough for rodents to enter the godown when closed. This was usually due to doors being bent out of shape, broken hinges, guard plates missing or actual doors missing.

Floors - marked as defective if they were cracked (more than 1 cm wide), floors had sagged or dropped, if they contained holes or rodent burrows, if grain was germinating in cracks. We did not count as defects the expansion joints in the floors unless more than 1 cm wide.

Windows - Marked defective if glass or screens were broken, torn or missing.

Walls - Marked defective if plaster or concrete had broken away from surface,or if they had holes or cracks.

Roofs - Marked defective if there were cracks and/or leaks, or with cracks in the joints between the pillars and roof.

4. **Severity of Rodent Infestations**

Few - One to 10 rodents (mice or rats) estimated per godown based upon abundance of fecal droppings, dead or live rodents seen and no evidence of bag damage.

Medium - Ten to 25 rodents estimated per godown, fecal droppings easily seen in spilled grain or in unswept areas, little bag damage, live or dead rodents seen, few rodent burrows outside godown.

Severe - Twenty five to 100 or more rodents estimated per godown, numerous fecal droppings and distributed everywhere, obvious bag damage (gnawed holes), live or dead rodents seen and/or numerous rodent burrows outside godowns.

5. Severity of Bird Infestations

Few - Few bird droppings or feathers found inside godowns, occasional sparrow or pigeon seen inside and/or feeding on spilled grain outside.

Medium - Ten birds or more seen inside godown, obvious bird droppings on bags or in grain, numerous sparrows and/or pigeons feeding outside.

Severe - Many birds (more than 50) flying inside and outside godown, many droppings and feathers throughout godown interior, presence of nests inside godown.

To check on the estimated sizes of the rodent infestations as given above, the godowns with the several estimated rodent infestations (low, medium, severe) would have to be trapped and animals captured and removed until no more captures could be made. These total animal counts would then be compared with the estimates to obtain a standard infestation rating.

B. Damage Assessment Methods in Wholesale Grain Markets

Rodent infestations in wholesale grain dealers shops generally are at serious levels. This is because there are usually no attempts made to control the rodent population so they are naturally at or near peak levels that can be sustained in the environment. Food supplies are virtually unlimited, so living space and animal numbers are the only factors limiting population size.

Damage assessment methods in wholesale grain markets must rely upon trapping and removal of some of the rodents and some measurement of activity of the population. Based upon these two, removal of some rodents and a change in activity, the original population can be estimated. Then, knowing how much grain an average-sized rodent consumes daily, the amount of losses from consumption can be estimated.

To carry out this procedure, inked or chalked tracking tiles are set first for one night in 8 to 10 shops that are to be trapped. These are scored positive or negative (Fig. 1) the next day. Then traps are set for 6 to 10 nights and as many rodents as possible are removed. The number captured daily is recorded. After 6 to 10 days, trapping is finished and again tracking tiles are set for one night.

Fig. 1. Rodent footprints on tracking tiles

The rodent population is estimated in two ways: 1) from the change-in-ratio (CIR) of positive tiles before and after removal trapping; using the number of animals removed as part of the calculations, and 2) from the regression of cumulative captures on daily captures, estimating the population where the regression line intercepts the x-axis. The estimated population is then multiplied by the amount of grain a roof rat eats daily to obtain the amount of grain lost in the 8 or 10 shops per day. The amount lost in one year is 365 times the daily loss.

C. Damage Assessment Methods at Farm and Village Level

The losses of stored grains at farm and village level are carried out as given above, using tracking tiles and removal trapping. The main rodents found living in farm structures in Pakistan are roof rats. House mice constitute a small proportion of the animals trapped inside structures and the Indian gerbil, *Tatera indica*, occurs as a peri-domestic species around outbuildings. Losses of stored

foods are calculated from the estimated number of rodents in each farm structure, using the average daily consumption of grain by roof rats and house mice as the amount of food lost.

D. Damage Assessment Methods in Field Post-Harvest

When wheat or rice is bundled and left in the field to dry before threshing, losses can occur due to rodents and birds feeding on the bundles. Losses of this kind are difficult to measure since it may be very severe in one field and very little in another. Losses would have to be measured in many fields (100 or more) to cancel out these extreme values. Panicles would have to be taken from bundles exposed to rodent and bird attack and from those bundles protected from attack. The differences in weight between protected and unprotected panicles would represent the loss. The actual loss of entire panicles would have to be accounted for also.

VERTEBRATE PEST SURVEY
OF FOOD STORAGE FACILITIES

Appendix-1

District _____ Town _____ Date _____

Name and Address of Facility _____

Manager's Name/Person Contacted _____ Govt. [] Private [] Other []

Number of Employees/Titles _____

Pesticide Application: fumigant Used _____

Schedule of Treatments _____ Frequency of Inspection _____

Any Other Control Methods: Traps [] Predators [] Barriers [] Other [] .

Training Needs: Present Refresher Training Given: Yes [] No []

Schedule of Training _____ Duration of Training _____

Godown No. _____ Stored Food _____ Quantity _____ mt. Duration _____ mo.

Quality: Excellent [] Good [] Fair [] Poor [] Bagged [] Bulk []

Bulk under tarps outdoors [] Bagged under tarps outdoors [] Bagged outdoor uncovered []

Structural: Type of structure _____ Age _____ Capacity _____

Structural condition: Good [] Fair [] Poor []

Structural Defects: Yes [] No [] Doors not fitting [] Floor cracked/broken []

Wall cracked [] Windows unscreened/broken [] Leaking Roof [] Grilled doors []

Vertebrate Pest Problems: Yes [] No [] House mice [] Roof rats [] Other rodents []

Pest Birds [] Other vertebrates [] (Cats, dogs, bats, etc.)

Severity of infestation: Rodents: Few [] Med [] Severe [] Birds: Few [] Med [] Severe []

Evidence: Droppings [] Live or dead animals [] Burrows outside [] Burrows inside []

Kinds of damage: Food consumption [] Contamination [] Bag damage [] Structural []

Remarks: _____

CULTURAL METHODS IN VERTEBRATE PEST MANAGEMENT

By Joe E. Brooks

Cultural methods in vertebrate pest management involve changing agricultural practices from those practiced presently to new ones that will evade or minimize crop damage. Interestingly, the methods used to reduce rodent infestations and crop damages are quite the opposite of many of those used to reduce bird damage to crops. In rodent control, the main idea is to reduce or eliminate areas that contain excess vegetation, such as weeds, grasses, and shrubs, as these serve as food and cover for rodents. In bird damage reduction, one may want to leave areas of natural vegetation so these will provide alternate food sources for the birds and divert them from the field crops. If both kinds of vertebrate pests are present, the pest management specialist may have to decide which is the more important strategy in light of which pests are the most damaging.

A. Rodent Damage Reduction

Clean farming practices can do much to discourage rodent infestations and make it easier to detect and deal with them when they do occur. Around farm buildings, which often present many natural attractions to commensal and field rodents, it is particularly important to eliminate the rodent cover provided by the accumulations that tend to build up of discarded equipment, log piles, rubbish of various kinds and dense vegetation growing in neglected corners. Weeds and grasses should be kept cleared away from farm buildings for a distance of at least 25 m to discourage field rodents from infesting the structures following harvest.

Spillage of grain and similar products should always be cleaned up immediately. Stored grain and animal foodstuffs should be kept in rodent-proof containers. If this is not possible, as in bagged storage, then the stacks of food should be kept small, with a clear passage left around the outside of each stack to provide easy access if a rodenticide treatment should be required. Places where livestock are kept and fed should be maintained as clean and tidy as possible. Animal feeds spilled during feeding should be gathered up immediately and either discarded or mixed with the fresh feeds for the next day.

On arable land, it is advisable to eliminate cover by clearing nearby uncultivated areas of weeds, bush or scrub, including field edge habitats and the banks of ditches and other water courses. Field edge habitats for rodents may also be eliminated by consolidating small fields into larger cultivated tracts. Efficient weed control during the growing season discourages the development of rodent infestation, as does prompt and efficient harvesting. In the post-harvest period, it is important to eliminate crop trash, for example, by burning, and to plough the field as soon as possible in order to disrupt any residual food supply that is left in the field.

For example, farmers should practice weed and grass control on the bunds and in the fields of wheat, rice and groundnut to eliminate or reduce the food and cover these plants normally provide to rodents. Both the lesser bandicoot rat and the short- tailed mole rat feed on the roots, tubers and rhizomes of grasses and weeds growing on bunds. The rhizomes of *Sorghum halepense*, (Johnson's grass) and *Desmostachya bipinnata* are subsistence foods of both species of rats year round and especially during the inter-crop periods. Elimination of these from bunds and field interiors would help to reduce the rodent populations infesting rice, wheat and groundnut fields.

B. Wild Boar Damage Reduction

One cultural practice that would help to reduce cover and resting places for wild boar in sugarcane fields would be to break up the large fields of cane as presently planted and reduce the largest blocks into those no larger than one-quarter to one- half acre. Or alternatively, plant cane in strips no wider than about 25 m. The reasons being that wild boars prefer to hide, rest and breed in the larger tracts of sugarcane because here they are best protected from harassment by dogs and humans. If the blocks were made much smaller, especially if there were open lanes or passages between blocks which could be easily patrolled, the wild boar would find it difficult to use such fields.

Another method to use in wild boar damage reduction, would be to plant the cane varieties in synchrony, i.e., soft-rind varieties all planted at the same time so that they ripen together, and harder-rind varieties all planted in synchrony. As now happens, the soft-rind fields are attacked first and individually because their sugar content tends to rise early and they are selectively damaged.

C. Bird Damage Reduction

Several cultural practices for reducing losses due to birds apply to nearly all crops. If possible, avoid planting vulnerable crops near breeding, roosting, and loafing cover preferred by the species causing damage. If impractical to avoid planting adjacent to such preferred habitats, timing plantings so that the sprouting and ripening periods are in synchrony with other plantings in the locality lessens the vulnerability of that planting to birds. Crops that sprout or ripen before others in an area are more susceptible to heavy damage from assemblages of local breeding birds; crops that ripen very late are often severely damaged by migrating birds. Leaving crop stubble for birds to glean as alternate food sources also lessens damage in unharvested crops. In tilled crop fields, delaying tillage until other vulnerable crops have been harvested provides sources of waste grain and weed seeds that furnish birds with a part of their diet that is not a marketable crop. Finally, harvesting the mature crop as soon as practical lessens damage from birds that prefer the mature crop stage.

If changes in crop phenology, that is, planting or harvest times of the food crop being threatened by birds, can be made, it is perhaps the easiest way to avoid bird problems. Where migratory birds are known to appear regularly at a certain time each year, it should be possible to plant a little earlier in the crop season so that the plants will be large enough to avoid the sprout pulling which would normally occur.

If it is not possible to alter crop phenology, then it may be possible to try crop substitution or diversification, especially in monocultural areas. It may be possible to use a different crop rotation schedule to avoid the use of crops normally damaged by birds. In monocultural areas, sometimes the use of more crop diversity, i.e., the use of several different types of other crops mixed with the predominant crop, will help to reduce bird damage to the main crop.

Site selection often plays a prime role in whether a particular field crop is damaged. Planting sunflower or maize near groves of trees or tree rows around fields often will lead to increased attack on the crop by rose-ringed parakeets. Plant these field crops well away from trees, if possible.

Bird-resistant crop varieties, especially those of sorghum, can be used to reduce damage to this grain crop. Varieties that tend to produce higher levels of tannins appear to be more resistant to bird damage but their palatability may be reduced because of the tannin levels.

The cultural practice most likely to reduce bird damage to sprouting maize is deep planting. Maize seeds planted more than 5 cm deep suffered less bird damage in the USA than shallower

planted seeds and maize planted more than 7.5 cm deep in clay soils in Iowa, USA suffered no losses at all despite some bird species feeding in the same fields on other seeds. What the proper depth should be to prevent damage by the mountain or jungle crow is not known at present.

Provision of alternate bird foods, through practices such as using crop diversity, buffer plantings, and delayed tillage, will help in reducing bird damage. When alternate foods are available, birds will do a good amount of their feeding on these, instead of the more valuable and vulnerable crop. Planting buffer crops in rows on the perimeter of the vulnerable crop is another means of diverting birds from the more valuable food source. Delaying tillage of the harvested fields will leave the seeds and grains from the previous crops as available foods for birds and keep them from damaging the newly planted areas.

Sometimes, damage from migratory birds can be reduced or avoided by planting and harvesting the crop early. In this way, the crop is gathered before the birds arrive. Planting and harvesting early may result in reduced production but this should always be weighed against the losses in yield if the regular planting schedule is followed.

Clean farming can reduce damage to ripening rice by some bird species. Clearing away brushy field borders, used by birds for cover and roosting and loafing areas, does much to reduce damage.

For the most part, changes in agricultural practices could go far in solving the majority of bird-pest problems, nearly always to the benefit of the ecosystem, in that birds could be retained as predators in the system and it would be unnecessary to add poisons aimed at bird control.

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TRADITIONAL AND NON-CHEMICAL METHODS OF RODENT CONTROL

By Iftikhar Hussain and Ejaz Ahmad

The most important factor in rodent control is to be aware of the problem. We call this VIGILANCE, which means a person must inspect his fields, houses and godowns often and regularly. In fact one should also inspect neighbouring fields, dikes and buildings as well. As soon as the first sign of a rat appears, the animal should be killed by any method available. Inspection of an area also helps in planning the control activity, that is to contact people (neighbours) to be involved, where to place traps or poison, whether a store should be cleaned and tidied first, holes be closed and doors and windows should be fixed.

Some methods of controlling rodents without toxicants have been used for centuries. Trapping, for instance, can be very successful where carried out correctly. However some of the most modern methods, such as the use of ultrasound, electromagnetic waves, attractants, repellents, and chemosterilants, have been less successful.

A. Habitat Manipulation or Modification

1. Houses and Buildings

All animals are dependent on food and shelter. Therefore, elimination of one or both of these requirements will force them to move from the immediate areas. All waste, edible or otherwise, should be correctly stored so that it does not provide harbourage or food, and then adequately disposed of. All materials should be stored on racks so that inspection for an infestation is made easier (Fig. 1) and storage of any goods or waste should be as short as practicable. Whenever possible all access to water sources should be denied to rodents. Leaky taps, broken drains, etc. should be repaired immediately. So good house keeping and good sanitation and hygiene procedures should be followed. In the control of commensal rodents, it is essential that garbage and refuse be placed in covered metal containers and the premises be kept clean. To reduce cover, materials stored outside should be off the ground and not stacked against or near walls.

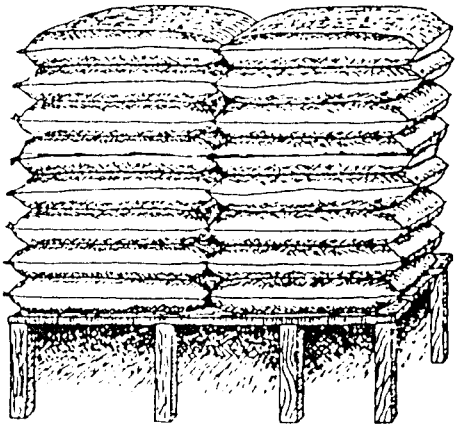

Fig. 1. Proper storage of stacked materials.

In poultry operations, keep manure piles away from chicken houses and place brooder houses in open, clear areas to reduce rat problems.

2. Rodent Proofing

Buildings and food storage containers can be made rodent proof by ensuring that no gap in the structure is more than 7 mm wide. The materials used in construction must be, like brick, concrete or metal, resistant to penetration by rodents. The common points of access into buildings for rodents are poorly fitting doors and windows, ventilators and eaves, and holes where pipes or cables pass through the exterior walls. Unnecessary holes should be sealed with cement. Openings required to provide

ventilation should have permanent screens fixed over them, made from metal mesh such as 6 mm, 24 gauge expanded metal, which should be painted to prevent rusting. Wooden doors and door frames are vulnerable to gnawing near the base. This can be prevented by fitting 20-gauge galvanized iron sheet upto a height of approximately 30 cm on the outer face of the door and frame (Fig. 2).

Buildings made from traditional materials, such as mud and wattle, or with thatched roofs, usually cannot be made rodent proof, and it is better in such cases to concentrate on rodent destruction techniques and the use of rodent-proof storage containers. New buildings constructed from modern materials should be of a rodent proof design. Usually it is desirable to direct the attention of architects to the specifications required.

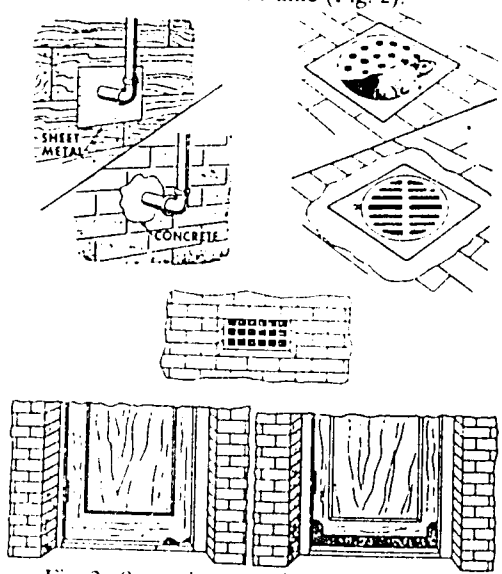

Fig. 2. Several types of rodent-proofing.

3. Clean Farming Practices

Clean farming practices can do much to discourage infestation and make it easier to detect and deal with infestations when they do occur. Around farm buildings, which often present many natural attractions to commensal rodents, it is particularly important to eliminate the cover provided by the accumulations that tend to build up of discarded equipment, log piles, rubbish of various kinds and dense vegetation growing in neglected corners. Spillage of grain and similar products should always be cleaned up immediately. Stored grain should be kept in rodent-proof containers. If this is not possible, as in bagged storage, then the stacks of bags should be kept small, with a clear passage way left around the outside of each stack to provide easy access for inspection and treatment.

On arable land, it is advisable to eliminate cover by cleaning nearby uncultivated areas of weeds, brush or scrub, including field edge habitats and the banks of ditches and other water courses. Field edge habitats may also be eliminated by consolidating small fields into larger cultivated tracts. Efficient weed control during the growing season discourages the development of rodent infestation as does prompt and efficient harvesting. In the post-harvest period, it is important to eliminate crop trash, for example, by burning, and to plough the field as soon as possible in order to disrupt any residual food supply that is left in the fields.

B. Lethal Methods

1. Trapping

Trapping rodents is one of the oldest methods of rodent control. It is still a satisfactory method for controlling rodents in a limited area. It also gives the farmer or godown (warehouse) keeper the satisfaction of knowing the rodents are destroyed as he removes them from his traps.

Trapping has several advantages besides killing rats. It enables the species of rat which is causing the damage to be identified, and in this way its pest status determined. Also, trap success will give an indication of rat population density. This is generally calculated by finding the percentage of rats caught per 100 trap nights.

Different types of traps are available. Basically there are those that kill the animal upon being trapped, KILL OR SNAP-TRAPS, and traps in which the animal is caught alive, LIVE TRAPS(Fig. 3). The live traps are of two general types, one is a long, round wire cage called the "wonder trap" which

the rat enters through a one-way trap door. The other is a wood box with a snap-down door. Both of these traps work, but they are bulky and hard to adjust so that they work properly.

The snap or break-back traps are made of stamped out sheet metal, they are much cheaper, more effective and easier to set and adjust. They can be set in places favoured by rats. Before setting traps ensure that they are in good working order, that trigger plates work freely and release easily.

2. Setting Traps Indoors or in Built-Up Areas

Rats like to frequent secluded, sheltered places, so the trapper should seek out such places in which to set traps. Set traps so that they are at right angles to walls or other solid objects, because rats prefer to run next to walls rather than across open spaces. Place traps away from areas where they will be disturbed by people or traffic. It is best to set traps late in the day and leave them overnight, for rats are generally night feeders. It is generally advisable to pick them up as early as possible the following morning. The bait should be replenished at least once every 24 hours. One advantage of trapping is that the rats so caught can be removed and disposed of whilst poisoned rats often die in inaccessible places and create smells.

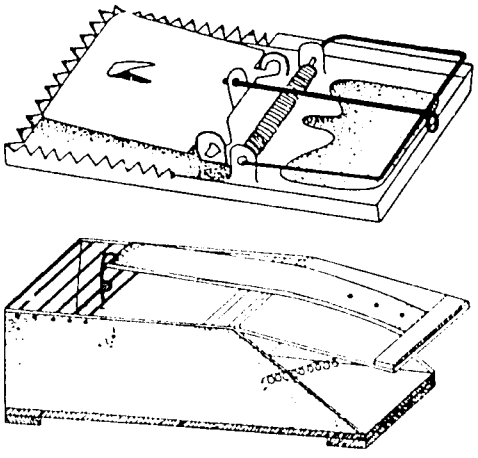

Fig. 3. Several types of rat traps.

3. Field Trapping

Control of field rats by trapping is very expensive unless the area to be protected is small. Many traps would be required and they would need daily attention. Set the traps near rat-holes or rat runway if possible and "flag" the trap by tying a scrap of cloth on a piece of vegetation near the trap. Conventional type traps only work on those rodents which feed on the surface. One major rodent pest, *Nesokia indica*, the short-tailed mole rat, seldom moves about on the ground surface, inflicting mainly subterranean damage. It cannot be controlled, therefore, by conventional surface traps. Unfortunately, special mole or gopher-type traps which are effective are not available in Pakistan.

4. Trap Baits

Trap success is often dependent upon correct bait selection. An effective bait must possess several physical properties. It must not spoil rapidly, it must not be too brittle to be easily affixed to the trap trigger, and the rats must like it. To select the most appropriate bait, the species of rat expected to be trapped should be known. Nut meats are good baits for commensal as well as field rodents, but are expensive and hard to affix to the trap triggers. Peanut butter can be smeared on the trap bait triggers and thus will attract a wide variety of rodents, but in warmer weather it suffers from the attention of ants which may eat or remove all the bait in one night. Ants may repel the rats if they are numerous around the trap platform areas.

In general a satisfactory bait for field and domestic rodents are pieces of fresh "nan" and chapati (unleavened wheat bread). These two baits have the advantage of being cheap, having the right physical properties, and readily available. Another effective bait is fresh onion, which is not attractive to ants, but is difficult to affix on the trap trigger. It is ideal for use in live traps. In conclusion, always use the proper bait, replenish with fresh bait daily and change the kind of bait after one or two days if acceptance is poor. Remember that the bait has to be more attractive than the crop or product being protected, if it is to be effective.

5. Smoking and Watering

In the field, rats can be driven out of burrows by pouring water or by using smoke (with chillies) blown into the burrows. If available, a net should be placed on top of the burrow system to prevent rats escaping. Many people should be involved to kill the escaping rats. Digging out is most effective and sure. It is found that almost all burrows contain only one adult animal. If it is a female, young should be looked for. Breeding females are easily recognized by swollen teats.

In some areas fields can be flooded to kill rats after sugarcane has been harvested. The land is heavily irrigated to plough in cane root stocks and farmers often notice short-tailed mole rats swimming for safety to the field embankments. Therefore, before doing this, be sure to destroy all cover that the rats might flee to when they are driven out.

6. Glue Boards

Pieces of cardboard or wood coated with rodent glue, a very sticky, resinous material, placed in strategic positions are sometimes used to entrap rodents, particularly house mice. The use of glue boards is widely considered to be inhumane. Furthermore, they are of very limited efficiency, since the glue loses its adhesiveness in dusty, wet or excessively warm or cool conditions. The method is therefore unsuitable for use in agricultural rodent control.

C. Miscellaneous Barriers

Many other devices have been proposed or experimented with as methods of preventing rodents from gaining access to vulnerable areas and commodities. These devices include ultrasound generators, ultraviolet lamps, magnetic devices, chemical repellents and electric fences. None of these can be considered practical or effective for ordinary agricultural applications. A simple fence consisting of sheet metal has been used for rare occasions to protect bulk grain stored in the field. The fence should be at least 60 cm high and be dug at least 45 cm into the ground, with a further 15 cm turned outwards at the top to form rat guards, making a total sheet width of at least 120 cm. Any support posts should be inside the barrier.

D. Biological Control

The biological control of rodents through natural predators is a very common topic when rodent control is discussed. It can generally be stated that the use of animals like cats, dogs and snakes, which are known to kill and eat rats, is ineffective for economic rodent control under most field or godown conditions. It is a rare cat that can catch a full grown rat. Adult rats are too large and aggressive and often injure the cat when a capture attempt is made. Cats, therefore, generally confine their attention to mice and small immature rats. Dogs and snakes can kill rats but not in such effective quantities, as to result in rodent control. For dogs, cats and snakes, like all predators, only catch the rodents that are easily available. When hunting gets too difficult, because of a reduction in the prey population, they move to different hunting grounds. Usually the rodents left behind when hunting becomes too hard, still do economic damage, particularly in godowns. Such predators undoubtedly help to limit and control population numbers but by themselves cannot be relied upon.

Another form of biological control is through the introduction of diseases that kill rodents. Attempts have been made in the past, particularly in the Soviet Union to use *Salmonella* bacteria to infect rodents and kill them with gastroenteritis. This killed some rodents, but the surviving population soon developed a partial, and then total immunity. Another problem lies in the fact that disease could also be passed on to humans through food contamination.

RODENT PROOFING AND EXCLUSION METHODS IN GRAIN GODOWNS

By Joe E. Brooks and Iftikhar Hussain

A. Introduction

Rats, mice and birds are commonly regarded as vertebrate pests of stored foods worldwide. Losses of grains after harvest are considered equally as important as the losses that occur in the fields before harvest. The poorer the quality of storage conditions, the more likely that the grain stores are infested and the losses become serious.

In Pakistan, wheat is the major grain crop grown, harvested and consumed each year. Out of approximately 14 million metric tons (mt) produced, about 5 to 6 million mt are procured by the provincial food departments and the Pakistan Agricultural Storage and Services Corporation (PASSCO) and stored for periods ranging from one to 12 months until redistributed to the wheat-deficient areas of the country. Another 5 to 6 million mt remains in the hands of the growers, farmers, for their family consumption and for seed for the next season. One to two million tons are sold on the market immediately after harvest.

The quality of the provincial and PASSCO storage facilities and the severity of vertebrate pest infestations in the storage centres were surveyed by the Vertebrate Pest Control Project in 1986. In general, although the provincial storage facilities were in varying degrees of repair and in need of better physical maintenance, the consequent vertebrate pest problems were not considered severe. Total losses due to both rodents and birds were estimated to be only 0.3% to 0.6% of total stocks in storage, a total potential loss of 12 to 24 thousand mt throughout the country. However, even this minimal loss could be cut further through the use of proper pest-proofing and better physical repair and maintenance of the existing facilities.

B. Type of Problems Found

The kinds of structural defects noted in the provincial and PASSCO grain storage facilities are given in Table 1. For vertebrate pest infestations, the doors and windows are the most critical, since

Table 1: Structural Defects Noted in Provincial and PASSCO Grain Storage Facilities

Agency	No. Godowns Examined	Percent with Defects				
		Doors	Windows	Floors	Walls	Roofs
Punjab	181	35.9	34.2	47.5	51.9	17.7
Sind	85	78.8	34.1	76.5	88.2	7.1
NWFP	46	76.1	78.3	84.8	93.5	39.1
Baluchistan	24	70.8	66.7	50.0	66.7	16.7
PASSCO	56	17.8	0.0	1.8	30.4	0.0
Totals	392	49.5	36.5	51.8	60.7	15.6

these are the points of entry for the animals (rats, mice and birds). As is seen, almost 50% of the godowns inspected had doors in poor repair or ill fitting so that rodents and/or birds could easily move

into the structures. More than one-third of the godowns had missing screens or window glass, allowing easy entry by sparrows and pigeons.

Simple rodent- and bird-proofing measures are obviously needed in order to keep vertebrate pests out of grain storage facilities. It is best if these are designed as part of the original structure when it is built. Unfortunately, this is rarely done and proofing, or exclusion measures must be done later. We will briefly review the rodent- and bird-proofing measures that can be used in grain godowns.

C. Rodent-Proofing Measures

1. Rodent-Guard

The ideal way to keep rodents out of grain storage structures is to deny them access to the structure itself. This idea was incorporated into the design of the PASSCO house-type godowns where a rodent-guard was built into the structure (Fig. 1). The rodent-guard is an extension of the floor so that a shelf of smoothed concrete protrudes approximately 30 cm outward from the entire structure and is about 1 meter above ground. Rodents attempting to climb the foundation walls of the structure (as house mice and roof rats can do) will encounter the protruding guard and are unable to gain access to the doorways. In addition, the loading dock is built without stairs. This prevents rodents from gaining access to the dock and thereby entering the doors. A removable ramp is used to allow godown personnel access to the dock during the day. The entire purpose of the rodent-guard is defeated if stairs are built or placed next to the dock and left there. The rodent-guard is one of the important factors in why PASSCO godowns had very low rodent infestations when inspected in November 1986.

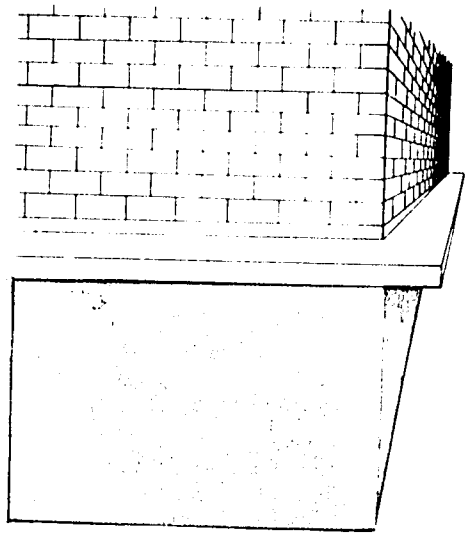

Fig. 1. PASSCO-type rodent-guard.

2. Doors

Probably more rats and mice gain entry to buildings through defective doors than by any other means. The doors usually are not fitted properly to keep rodents out or have become damaged and no longer close tightly. Doors should have no more than 1/4 inch (6.5 mm) clearance above the sill in order to exclude mice and rats (see Fig. 2 to see clearances for rat and mouse exclusion). If the doors are on tracks, they should close so that no space more than 1/4 inch is allowed. Doors should be fitted tightly into their sills and jambs so that total interior fumigation with phosphine can be done with a minimum of sealing around the doorway.

Fig. 2. Rats can given entry through holes as small as 1/2 inch (1.3 cm) in diameter; mice can get through a hole 1/4 inch (6.5 mm) in diameter.

The use of an inner door made of grilled mesh or expanded metal will keep out rodents and birds when there is need for the outer doors to be opened (Fig. 3), for instance for ventilation purposes. These are fitted inside the regular doors and swing inward.

Birds can be prevented from entering open doorways and those required to be constantly open during working hours by installing a vinyl plastic strip door, which allows persons or machinery to pass easily through but stops birds from doing so (Fig. 4).

3. Windows

Broken window glass and broken or missing screens are the means by which house sparrows and pigeons may most easily enter godown interiors. Screening of windows can be done with a variety of materials, including ordinary fly-screening in nylon or metal mesh, poultry mesh of small aperture or nylon or other netting. Screening can be done to individual windows or the entire row of windows could be screened as shown in Fig. 5. This kind of screening can be swung out of the way when there is a need to mud-plaster the windows for godown fumigation.

4. Ledges and Perches

Birds can be discouraged from using godown interiors by preventing them from landing and resting on ledges and perches on the buildings. Materials called porcupine wires are a relatively permanent method of keeping pigeons from roosting on structures. They are composed of many spring-tempered stainless steel prongs with sharp points extending outward at all angles. The prongs are fastened to a solid base which can be installed on window sills, ledges, eaves, roof peaks or wherever pigeons are prone to roost (Fig. 6). These sharp pointed wires inflict temporary discomfort and cause pigeons to avoid landing on these surfaces. In a few cases pigeons have been known to cover the wires with nesting materials, so they must be maintained. Although these devices and their installation can be expensive, the more permanent results may justify the cost.

A simpler way to keep pigeons from roosting on ledges is to fix a board or piece of sheet

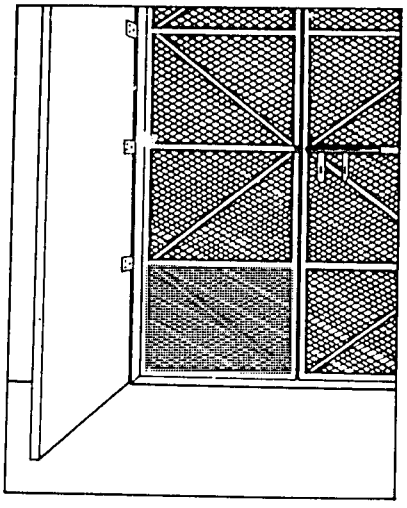

Fig. 3. Grilled inner doors keep out both rodents and birds.

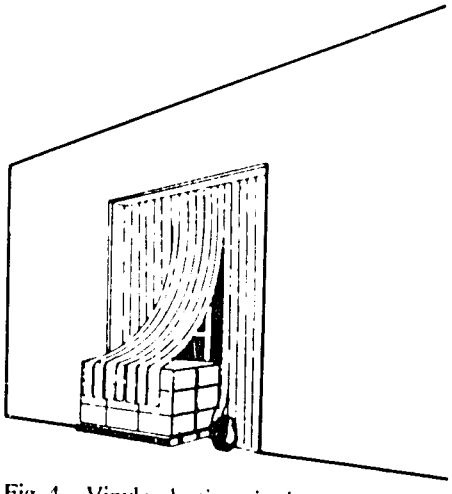

Fig. 4. Vinyle plastic strip doors stop birds from entering.

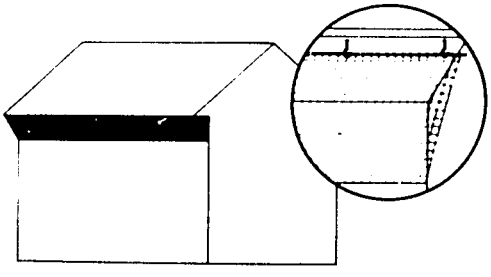

Fig. 5. Hinged screen for windows stops birds.

metal at a 45-degree angle across the bottom of the ledge (Fig. 7).

5. **Pipes**

Any place where pipe or electrical conduit enters the walls will have to be rodent- proofed. Sometimes these are installed after the structure is built and a hole has to be knocked in the wall. These openings should be sealed with either a plate of sheet metal, cut to fit tightly around the pipe and fastened securely to the wall, or the opening should be closed with cement (Fig. 8).

6. **Drains**

If the godown has floor drains allowing for runoff of wash water when the interior is cleaned, these will require grills or drain covers to keep rodents from entering by the drainage pipe (Fig. 9). These should be installed flush with floor so they do not become damaged by machinery used inside the godown. They should be hinged or screwed down so they can be lifted occasionally for cleaning.

If roof drain pipes are present on the outside of the godown, these need rat-guards installed to prevent rats from gaining access to the roof. Several types of sheet metal rat-guard that will stop rats from climbing a drain pipe are shown in Fig. 10. These are fitted over the outside of the pipe and fastened securely to the outer wall.

D. **Maintenance of Rodent- and Bird-Proofing**

Once a godown is completely rodent- and bird-proofed, then if rodents are inside, they should be eliminated. Either 1) fumigate the entire structure with phosphine, or 2) place anticoagulant or zinc phosphide baits packed in polythene bags inside at all places where rodents will find them and keep them out for two weeks or until no further bait takes are seen, or 3) place baited kill traps at all spots where rodents would be expected to travel. Continue trapping until no additional anin als are captured.

Inspect the inside of the godown and close all cracks or holes where rodents might hide or burrow. Make certain that no holes connect with the outside of the structure. If they do, close them off with good quality cement made into concrete. Concrete floors are best inside for where grain is to

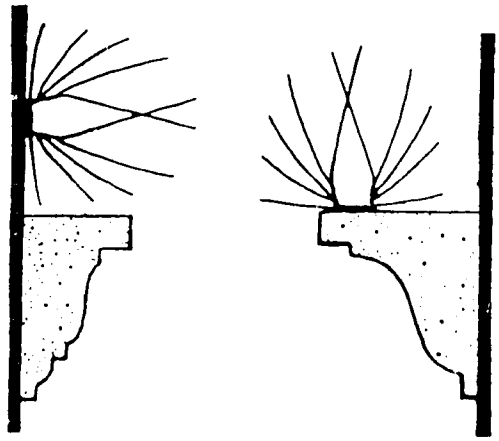

Fig. 6. Porcupine wires discourage birds from landing.

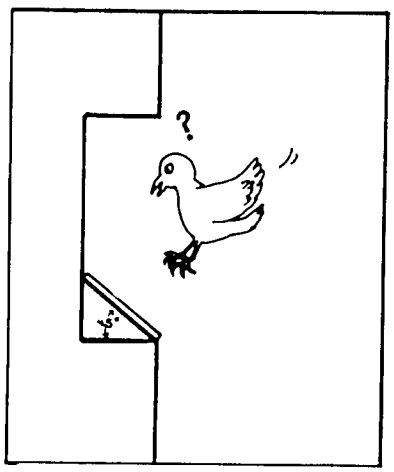

Fig. 7. An angled board or metal plate discourages roosting

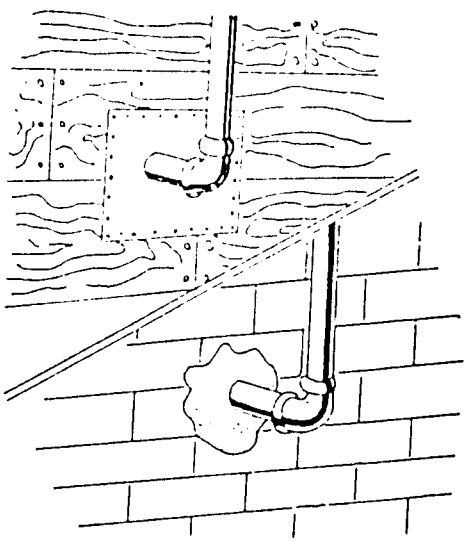

Fig. 8. Rodent-proofing of pipes.

be stored. Replace interior dirt or wooden floors with concrete to avoid pest problems.

When the godown or grain storage facility is rodent- and bird-proofed, it is important that the improvements be maintained. Doors and windows need to be kept in good repair and not allowed to become defective. If screening is torn or otherwise damaged, it should be repaired or replaced. Rat-guards and collars on drain pipes should be inspected regularly and made sure that they are intact. Ledges and shelves where birds may roost or nest should be inspected and steps taken to keep the bird-proofing intact. Floor drain grills should be in place and kept clean. Maintenance of proofing measures will require a regular inspection of all perimeter points where birds or rodents might enter the structure. This probably should be done every 6 months.

A rodent- and bird-proofed structure, once cleared of any residual pest infestation, should be permanently free of vertebrate pest problems inside for as long as pest-proof measures are maintained (Fig. 11).

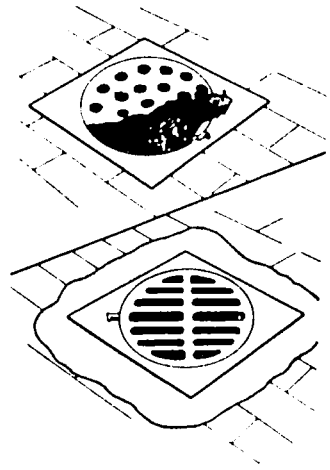

Fig. 9. Replace broken or defective drain covers.

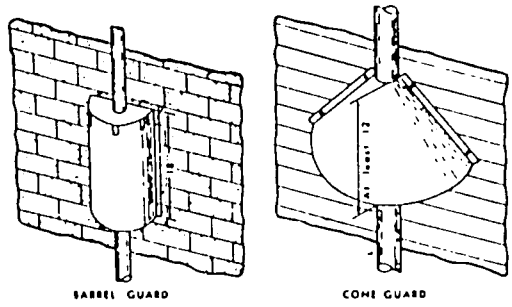

Fig. 10. Rat guards on roof drain pipes.

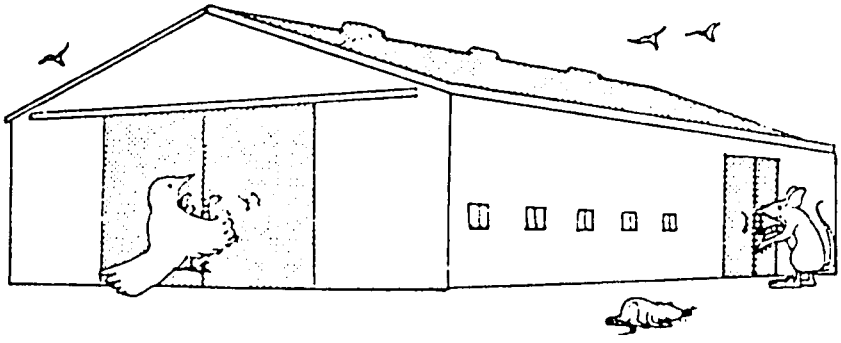

Fig. 11. A bird and rodent-proofed grain storage structure should be permanently free of pest problems.

RODENTICIDES: THEIR CLASSIFICATION AND PROPERTIES

By Abdul Aziz Khan

Introduction

Biocides, generally, are chemical compounds which kill living organisms and all those biocides which are used against pests are known as pesticides. Pesticides are further classified according to their specific use such as insecticides, fungicides, acricides, nematicides, herbicides, weedicides, etc. Those pesticides which are registered for their use against rats and mice are termed rodenticides.

Classification

Rodenticides, which are commonly organic or inorganic compounds, are classified arbitrarily (based on action) into four groups or kinds:

1. Acute or single dose
2. Chronic or multiple dose or anticoagulants
3. Fumigants
4. Chemosterilants

A. Acute Rodenticides

An acute rodenticide (Table 1) can be lethal following the consumption of one feed of bait. Most of the acute poisons currently marketed for the control of rodents have proven to be fairly effective but, at the same time, they are highly toxic to non-target animals such as birds and wildlife of national importance. Therefore, there can be high risks of accidental poisoning. They are relatively less expensive. Their continuous use, however, can cause bait-shyness and thus adds cost to the control operations. There is no good antidote for most of these poisons in case of accidental poisoning.

Acute rodenticide cause death as a result of:

1. Paralysis of central nervous system
2. Failure in respiration
3. Cardiac irregularities
4. Gastro-intestinal irritation (haemorrhage)
5. Haemolysis(destruction of red blood cells)
6. Destruction of kidney and liver tissue
7. Blocking of citric acid oxidation
8. Hypothermia

B. Brief Description of Acute Rodenticides

1. Zinc Phosphide

Zinc phosphide is an inorganic compound, commercially available as a finely divided, dense powder, having a black or greyish-black appearance with a strong garlic-like odour. It is soluble in dilute hydrochloric and sulphuric acids. When exposed to moisture, it decomposes slowly and releases phosphine gas which is highly inflammable. Zinc phosphide is a fairly stable compound when kept dry and hermetically sealed.

Zinc phosphide is effective against both urban and field rats. It is generally used at a strength of 1 or 2%. At higher concentrations it is less acceptable to rodents. Its garlic-like odour appears to be attractive to rodents unless bait shyness has developed, whereas this smell tends to repel man and domestic animals to some degree. However, carelessly exposed baits have proven to be lethal to domestic poultry. Since this compound is toxic to all farm animals, great care must be employed in its use.

2. **Thallium Sulphate**

Thallium sulphate is an inorganic stable compound which has limited solubility in water and only a slight odour and taste. It is supplied as a white powder that is very heavy. Thallium sulphate has been used most effectively for rodent and predator control, due primarily to its ready oral acceptability by most species. For field rat control, it is used at 1.5% in baits. It has also proven to be an excellent poison against commensal rodents but should be used only under tightly controlled and protected conditions because of its widespread toxicity to birds and non-target mammals. It is therefore a high risk poison which can give rise to problems of both primary and secondary poisoning of non-target species and therefore, its use, except in exceptional cases, is not recommended. In most Western countries, its household use has been totally banned.

3. **Strychnine Sulphate**

This organic alkaloid is prepared from the seeds of *Strychnos nux-vomica*. It is commonly used for killing dogs, cats and birds in many countries. In micro-doses it is used as a powerful stimulant.

The commercially available preparation is a white or greyish-white powder. It is quite stable, insoluble in water but soluble in many organic solvents and dilute acids. It is not absorbed through the intact skin. It has an extremely bitter taste which seems to interfere with its success in rodent control campaigns. Many rodent species, during initial exploratory tasting, learn its toxic effects and reject the strychnine baits on repeated application. Moreover, the material is hazardous to human beings and to domestic animals. It is therefore rarely used nowadays in rodent control.

4. **Red Squill**

Red squill is one of the oldest known rodenticides. It is derived from the bulb of an onion-like plant, *Urginea maritima*. The active "rat killing" ingredients are glycosides of which "Scilliroside" has been obtained in crystalline form. Red squill powder deteriorates at temperatures in excess of 80^{0}C. The powder also looses its toxicity when it remains in contact with moisture. It is extremely irritating to the skin but is not absorbed by the skin. It is comparatively safe to humans and animals which can vomit because it acts as its own emetic.

Red squill powders and extracts are used primarily for the control of Norway rat. Even with its bitter taste it is fairly well accepted by this species. This bitter taste can cause bait shyness, however.

5. **Alpha-Naphthyl Thiourea (ANTU)**

This compound is a fine bluish-grey powder, stable, non-volatile and insoluble in water and oil. It is soluble in some organic solvents. It is odourless and tasteless and not absorbed through the skin.

ANTU gives excellent and safe control of Norway rats but roof rats and house mice are much more resistant to its action. It can cause bait-shyness when used over a long period. Recently it has been established that the compound may be carcinogenic and its use has been banned in USA and some other countries. It is highly toxic to dogs, cats and pigs. Since the Norway rat is not a major pest problem in Pakistan, "ANTU" is not suitable for use in this country.

6. Arsenic Trioxide or White Arsenic

This is the oldest of all poisons and still in use. It is practically tasteless, insoluble in water and very stable in baits. At one time, arsenic compounds were widely used for rat control. Their use has sharply decreased in recent years either due to replacement by new, more effective toxicants or because of restrictions imposed on their use. They are highly dangerous to man and other mammals and birds.

Because of its high human toxicity, it is certainly not a material that should be made available for commercial purchase nor should it be used in mass rat control operations. Even for its restricted use, baits prepared with this compound should also include tartar emetic, which if ingested by humans will induce vomiting.

7. Barium Carbonate

Barium carbonate was used in rodent control for many years and, in fact, is still used by some Government agencies in Pakistan and India for urban rat control. It is a relatively safe rodenticide in the sense that few accidental poisonings have occurred from its use. It is an ineffective toxicant because so much poison is required in the bait to kill rats that they can easily detect it.

8. Norbormide

This compound is unique in that it has very little toxicity for the cat, dog, chicken, duck, primates, sheep or swine. This is the safest of all rodenticides but is poorly accepted by rats. The technical material was sold commercially as "Shoxin" and the formulated compound was called "Raticate". Norbormide is characterized by a high degree of specificity for Norway rats, and it has no effect on other rat species and mice. It is usually used in baits at a concentration of 1%. It has been shown that Norway rats can detect the presence of this compound in baits almost immediately, resulting in very poor bait acceptance and kill. It is no longer marketed.

9. Sodium Monofluoroacetate (1080) and Fluoroacetamide (1081)

These compounds are white crystalline powders, stable and highly soluble in water and tasteless. They are relatively insoluble in many organic solvents and in vegetable fats and oils. These compounds are hygroscopic and should be kept in hermetically sealed containers. A black dye is added to 1080 while 1081 is still sold as a white crystalline powder. Black dye is added so that 1080 can be distinguished easily from sugar, flour or other food items. Sodium fluoroacetate is one of the most effective rodenticides known but should be handled only by highly trained rodent control operators because of its vary hazardous nature to non-target species. Field rats are highly susceptible to "1080" and it is also used for predator control with high success. Mostly these two compounds are used for derating ships as recommended by WHO for this purpose.

Fluoroacetamide has some advantage over "1080" because its mammalian toxicity is somewhat lower. It seems to be more effective than "1080" in controlling rats in sewers.

10. Phosphorous (Yellow)

Yellow phosphorous has been used mainly in commercial preparations for home use and is quite effective particularly against Norway rats. Before the advent of thallium, it was often mixed with cereal grains for control of field rodents. It is hazardous to man and domestic animals. It has been replaced by anticoagulants in household use and its sale and use is forbidden in certain countries.

11. Pyrinuron (Pyriminal or Vacor)

This organic compound is effective against a broad spectrum of pest rodents and was considered initially as having a wide margin of safety to non-target animals. It does not cause bait shyness and gives no secondary hazards. Recent laboratory tests have indicated that it might produce carcinogenic effects and affect insulin production in humans and cause high blood pressure to workers during its manufacture. Consequently, it has been removed from the worldwide market.

12. Bromethalin

Bromethalin is a unique, highly potent organic compound which exhibits a mode of action different from other acute and anticoagulants. Bromethalin provides a lethal dose to rodents in a single feeding with death generally delayed two to three days and further feeding is inhibited.

Technical bromethalin is a pale yellow, odourless and crystalline solid. It is soluble in many organic solvents but essentially insoluble in water. Technical bromethalin is stable under ordinary storage conditions.

Other acute poisons, not mentioned in this chapter, sometimes used as rodenticides, are dieldrin, DDT, endrin, crimidine and alphachloralose. Information on toxicity to mammals, birds, humans and their use in baits of the compounds described are shown in Table 1.

C. Anticoagulants

1. Description and Chemical Structure

The development of anticoagulants as rodent control agents occurred during the 1950's, and undoubtedly marked a turning point in urban rodent control. They are gradually becoming widely used in the control of field rats also. These poisons act cumulatively after the rat has eaten the poisoned bait for several days. Rats do not associate poisoning symptoms with the bait material until lethal quantities have been ingested. Because of this, more complete control of rodent populations are possible with anticoagulants as compared to acute poisons.

The majority of the anticoagulants in use at the present time are derived from two groups, based on their chemical structure:

a) Hydroxycoumarins, e.g. Warfarin, Tomorin and Racumin. Brodifacoum, Bromadiolone, Flocoumafen.

b) Indandiones,e.g. Chlorophacinone,Diphacinone.

Most of the anticoagulants (Table 2) are quite stable compounds while their sodium salts are sufficiently soluble in water to permit their use as lethal liquid baits. These compounds are available commercially as pre-mix and master mix in the form of powder or liquid (oil-based) concentrates which are employed in the bait formulations.

2. Pharmacology

Anticoagulants reduce and ultimately totally prevent the clotting ability of the blood, as well as causing damage to blood vessels. They cause death by competitively interfering with the synthesis of

vitamin K in the liver. When the prothrombin level falls below a critical level, clotting cannot occur and the tiny haemorrhages throughout the body become major ones and the animal bleeds to death.

The mechanism by which anticoagulants prevent blood from clotting is more easily understood if we consider what happens when normal blood clots. If blood vessels are damaged by a cut or other injury, the liquid blood turns to a jelly which prevents further blood from escaping. What happens is that a soluble protein in the blood, called *fibrinogen* is changed to an insoluble mass of thread-like structure called *fibrin* which forms the clot. This change in the structure of the blood is initiated by the action of an enzyme called *thrombin*. Thrombin is formed from a blood protein called *prothrombin* by the action of another enzyme called *thrombokinase* which is liberated from the injured tissues under the presence of vitamin K. In case vitamin K is replaced by an anticoagulant, the whole process is interrupted (Fig. 1). The rate of blood clotting is gradually reduced and blood is lost until death occurs.

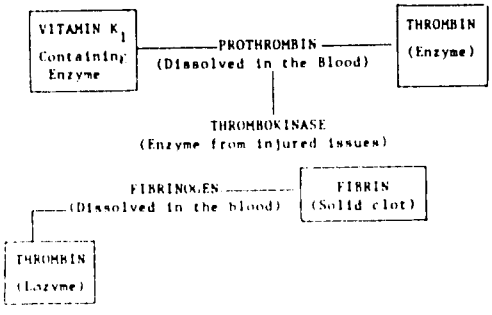

Fig. 1. Diagram showing changes in the blood leading to clotting.

The general effectiveness of most of the anticoagulants is about the same but some may be slightly better than others against a given species of rodents or those which have developed resistance to warfarin. Examples of such compounds are Brodifacoum, Bromadiolone and Flocoumafen. With these second generation compounds, rats die with one feeding but the process of developing lethal symptoms occurs within the same duration as in case of Warfarin and others of first generation rodenticides. Other general information about the anticoagulants is shown in Table 2.

D. Fumigants

Generally fumigants are used to supplement other rodent control techniques. Commonly used fumigants are aluminium phosphide, hydrogen cyanide, methyl bromide, carbon disulphide and carbon monoxide. Detailed description of their properties and use will be discussed in another chapter of this manual.

E. Chemosterilants

These are mostly organic compounds which temporarily or permanently sterilize the male or female rats. In general those working on females are more effective since they stop the production of young ones. Rodents in general are prolific breeders and one fertile male rat can breed with dozens of female rats. Therefore, a partial reduction in the fertile male population has no effect upon reproduction. Keeping in view this problem, a combination of toxic and sterility effects is desired in a compound which can be used effectively against urban and field rats. Alphachlorohydrin (Epibloc) is such a compound.

Epibloc is both an acute toxicant as well as a male sterilant agent (non-reversible sterility). Beside killing the rats, it also prevent the passage of sperms in adult male rats. This means that those rats left alive after feeding on the product are sterile. Epibloc is an acute (single dose) rodenticide and does not, therefore, require multiple feedings. Epibloc is more effective when rats are first prebaited with the same food stuffs used to formulate the finished bait. It is claimed that Epibloc is a new

concept in rodent control. Reports of its use in other countries are still awaited. There are reports of some problems with its acceptance in baits.

F. Ideal Rodenticide

What is required of an ideal rodenticide? The following are the desirable factors which should be present in a rodenticide and should be kept in mind during planning and operation of any rodent control campaign.

1. It should produce painless death.
2. Highly selective.
3. Readily degraded (only in dead animals or in the crop fields).
4. Odourless and tasteless.
5. Can be easily counteracted with an antidote.
6. Slow acting.
7. It should not create bait shyness.
8. Its use should not cause resistance or immunity to develop.
9. It should possess a high re-acceptance property.
10. In baits, it should have a long shelf-life.
11. Inexpensive.

G. Advantages and Disadvantages of Different Rodenticides

During planning of rodent control operations, besides considering the various biological and ecological factors, the selection of right type of rodenticide is highly desirable. In addition to technical reasons, human relations (environmentalist attitudes) and other socio-economic factors are involved in the success or failure of rodent control programmes. Therefore, advantages and disadvantages of the poisons used are always considered.

1. Acute Rodenticides

a) General Comments

Most acute rodenticides currently marketed for the control of rodents have proven to be fairly effective but, they are at the same time highly toxic to a broad spectrum of non-pest mammals, birds and other wildlife of national importance. So, there exists a risk of accidental poisoning of humans, pets, livestock and other non-target species when these poisons are being used by anyone other than a trained professional worker. Besides the economic losses caused by killing non-target species, accidents create widespread mistrust and misgivings and thus makes it more difficult to enlist the public support needed for the effective implementation of control programmes.

There are situations where the decision to use acute poisons is the most logical, such as when the disease hazard from the target species is high or in crop condition where the damage has to be prevented immediately so as to save the crop from total destruction. In field crops, the use of acute poisons is preferred because of less cost and replenishments of bait are not made as when using anticoagulants. Sometimes in sewer systems, slaughter-houses and warehouses, chronic poisons are not well accepted by rats, because in such situations excessive moisture makes it difficult to maintain chronic baits in a fresh and well accepted condition, necessary for continuous exposure needed for an effective kill.

Furthermore, the acute poisons, particularly the use of zinc phosphide, do not give kills better than 90% of the population and in such situations the population recovers and bounces back to its original level in a short period. For example, a rat poisoning campaign reduces the population by

about 75%. The population will return to its original level in approximately 6 months after the campaign is over.

b) Bait Shyness

Acute poisons have the potential of creating bait- shyness. Normally, what happens is that during control operations, a few animals do not eat enough poison bait to be killed. They may then develop a partial tolerance or shyness to remaining bait. How this bait-shyness or awareness of toxic baits is communicated from parent to offspring or to other individuals is not known. We need more information about the causes and prevention of both bait and rodenticide shyness. There are ways of overcoming bait shyness but overcoming rodenticide shyness may be more difficult.

Related to this phenomenon, it can be asked how long can a rat "remember" unfavourable experiences with toxic baits. Once bait is put out for field rodents, most of the survivors will refuse that type of grain for a few weeks or longer, even when offered to them unpoisoned. Thus subsequent control operations are not successful. Bait shyness can be overcome as follows:

i. Do not use acute poison baits more than twice a year or preferably only once.

ii. Change both the kind of bait material and the poison, preferably following with an anticoagulant.

iii. Use prebaiting in certain situations.

2. Anticoagulant Rodenticides

a) General Comments

In a majority of situations in the world, the anticoagulants are used for the control of urban and field rats. Because of multiple feeding, the rats show lethal effects and thus these poisons are reasonably safe for use around children, pets and livestock. Vitamin K or whole blood transfusions are effective antidotes. The rats while feeding on anticoagulant baits do not show any symptoms which makes it difficult for them to identify the causes of their sickness. Thus they do not stop eating the bait and consequently do not develop bait shyness. Rat population control of better than 90% can be achieved with the use of anticoagulants.

b) Resistance to Anticoagulants

Since the development of warfarin, this single anticoagulant was widely used till 1958 when natural resistance to it by *Rattus norvegicus* was discovered in Scotland and subsequently in other parts of Britain, the United States of America, Denmark, Sri Lanka and other parts of the world. Resistance is still confined to relatively small population pockets in Europe and is mostly found in the house mouse and Norway rat. Such resistance is not an acquired tolerance but is the result of a few genetically immune individuals surviving anticoagulant poisoning campaigns, and then passing this resistance from generation to generation through heredity. In any population exposed to continuous use of anticoagulants, 10% survivors is an indication that resistance has developed. In such situations control can still be achieved by shifting over to other types of anticoagulants such as brodifacoum, bromadiolone and flocoumafen etc. For information on how to determine the susceptibility or resistance of rats or mice to anticoagulants, see guidelines provided by World Health Organization Technical Report Series No. 43: pp. 140-147(1970).

Concluding the discussion, the advantages and disadvantages of the rodenticides are summarized as follows:

Acute e.g. Zinc Phosphide

Advantages

1. Fast action, dead bodies are easily located.
2. Cheap as technical material
3. Small amounts required
4. Emergency use

Disadvantages

1. Poison/bait shyness
2. Prebaiting required
3. Little selectivity

Chronic e.g. Warfarin

Advantages

1. Highly effective
2. Specificity
3. Antidote available
4. Lack of bait shyness
5. No prebaiting required
6. Birds are relatively resistant
7. Death is apparently painless
8. Hazards to other animals from a single accidental feeding are little.

Disadvantages

1. Slow action
2. High labour input
3. High cost of control operation

Table 1. Toxicity and characteristics of acute and subacute rodenticides.

Poisons	LD_{50}*	% a.i.	Effective against [a)] Rn	Rr	Mm	Accept-ance in baits	Soluble - water - oil	Hazard to man, l'stock	Hazard to birds	Not advised by WHO
ANTU	6-8	1.5	x			Fair	Neither	Medium	Low	X
Arsenic tricxide	13-25	1.5	x	x	x	Fair	Water	Extreme	Extreme	X
Bromethalin	2.5	0.005	x	x	x	Good	Neither	Medium	Low	
Fluoroacet-amide	13-16	2	x	x	x	Good	Water	Extreme	-	
Norbormide	12	1	x			Poor	Oil	Low	Low	
Phosphrus, yellow	1.7	1-3	x	x		Fair	Neither	High	High	
Pyrinuron	5-12	0.5-2	x	x	x	Fair	Neither	High	Low	X
Red squill	500	10	x			Fair	Both	Low	Low	
Sodium fluoroacetate	5-10	0.25	x	x	x	Good	Water	Extreme	High	
Strychnine	6-8	0.6			x	Poor	Water	High	High	
Thallium sulfate	25	1.5	x	x	x	Good	Water	Extreme	Medium	X
Zinc phosphide	40	1.0	x	x	x	Fair	Oil	High	High	

* LD_{50} values (mg/kg) for Rattus norvegicus.
a) Rn = Rattus norvegicus, Rr = R. rattus and Mm = Mus musculus

Table 2. Anticoagulant rodenticides and the percent of active ingredient commonly used in baits.

Common Name	Chemical Name	Percent active Ingredient in Baits
Brodifacoum	3-[3-(4'-bromo[1-1'biphenyl]-4-yl)-1,2,3,4,-tetrahydro-1-naphthyl]-4-hydroxycoumarin	0.005
Bromadiolone	3-[3-(4'-bromo[1-1'biphenyl]-4-yl)-3-hydroxy-1-propyl]-4-hydroxycoumarin	0.005
Chlorophacinone	2-[2-(4-chlorophenyl)-2-phenylacetyl]indan-1,3-dione	0.005
Coumachlor	3-[1-(4-chlorophenyl)-3-oxobutyl]-4-hydroxycoumarin	0.025
Coumatetralyl	4-hydroxy-3-(1,2,3,4-tetra hydro-1-naphthyl)coumarin	0.0375
Difenacoum	3-(3-biphenyl-4-yl-1,2,3,4-tetrahydro-1-naphthyl)-4-hydroxycoumarin	
Diphacinone	2-(diphenylacetyl)indan-1,3-dione	0.005
Flocoumafen	4-hydroxy-3-[1,2,3,4-tetra hydro-3-[4-(4-trifluoromethyl benzyloxy)phenyl]-1-naphthyl] coumarin	0.005
Fumarin	3-(2-acetyl-1-(2-furyl)ethyl)-4-hydroxycoumarin	0.025
Pindone or Pival	2-pivaloylindan-1,3-dione	0.025
Radione	2-(1-naphthyl)indan-1,3-dione	0.025
Valone	2-isovalerylindan-1,3-dione	0.055
Warfarin	4-hydroxy-3-(3-oxo-1-phenyl butyl)coumarin	0.025

CRITERIA FOR SELECTION OF BAIT MATERIALS, BAIT FORMULATIONS AND PREPARATION

By Iftikhar Hussain

Rodenticidal baits in which the active ingredient is mixed with an edible base are the most generally effective and widely used means of controlling rodents. Various aspects of bait formulation requiring consideration, including the edible bait base, the rodenticides and the use of bait additives. i.e. attractants, binders and color dyes, are discussed here.

A. Bait Materials

1. Bait Base

The bait base makes up the largest proportion of the bait and it should be selected on the basis of its preference to the target species, ready availability, and acceptable costs.

All of the cereal grains commonly grown in Pakistan can be used as rat baits. Some are favoured by rats. Tests in many countries under free choice situations have shown that maize is the best bait material, closely followed by oats, rice, and wheat. In general, the pulses and other food seeds do not make good rat baits, apparently not having the correct taste.

Preparation of grain for use as bait is another important factor for success. Maize must be cracked or crushed to the size of wheat or rice grains. Oats must be rolled or crimped and wheat should be crushed lightly or cracked. Only rice, easily available in the market in the broken form, needs no special processing, and it is reasonable in price and always available. Wheat prepared as "Dalia" is an ideal form for use as rodent bait. The reason for the cracking, crushing or rolling of grains is to aid in the adherence of the poison and/or its mixing in the bait. Poisons stick better to a broken surface than to seed coats or smooth grains. It is important to distribute the poison as evenly as possible throughout the bait, for if it is concentrated on the surface of a large seed, it will taste strong in relation to the unpoisoned interior and it may be discarded when the rodent husks or shells the seeds. This is the reason for using hulled baits.

The particle size of rodent baits is also important. The required size is sometimes difficult to accomplish without sophisticated crushing and mixing equipment. In Pakistan, the bait size resulting from using broken rice works well. Extensive tests have shown that rodents do not prefer flour-like or mealy baits. However, the use of flour-like bait constituents has the advantage of allowing the intimate mixing of poison and bait materials.

Most of the commensal rodent baits are a blend of two or more grains or cereals. The use of two highly preferred grains can be advantageous because such a blend has a better chance of being acceptable to a greater number of rodents in the population. Different rodent species may also prefer different grains.

Very often, especially for use on arable land and where food is in short supply, poorer quality materials may be satisfactory. However, it is usually necessary to use a higher quality bait to compete with the attractions of rodents' regular diet in places such as food stores and grain fields near harvest time.

In dry environments moist cereal baits often work well and water itself can be a very cheap and effective bait for use with soluble rodenticides.

Some of the acute poisons, like zinc phosphide, will kill grain-feeding insects. But the chronic poisons like Racumin and warfarin are non-toxic to insects so that insect-free grain must be used to prepare these baits, particularly if they are to be stored. The best way to kill insects in grain or baits is with fumigants like Phostoxin or Detia. Chemical contamination in foods will repel rodents. Baits should never be stored near strong smelling insecticides as this could adversely scent or flavour them. For the same reason, baits should not be made from grains treated with fungicides or a seed treatment.

2. Rodenticides (Toxicants)

The selection of the grain bait base is rarely influenced by the rodenticide used. However, with other kinds of non-grain baits, the rodenticide selected may greatly influence the way the bait should be formulated. For example, water soluble rodenticides can be used in water baits, but insoluble rodenticides cannot. Perishable baits, such as ground meat, fish or fresh fruits, can be used effectively with 1080 (sodium fluoroacetate), red squill, zinc phosphide or other acute rodenticides, since poisoning is generally accomplished in 24 to 48 hours. Perishable baits like these are not often used successfully with the first generation anticoagulants, such as warfarin, diphacinone, or chlorophacinone, because the bait deteriorates before the rodents have had sufficient time to make the necessary multiple feedings required. The use of perishable baits with these older anticoagulants would require successive applications of freshly prepared baits, which often is impractical or uneconomical.

The amount of rodenticide (i.e. % active ingredient) used in the bait may be very critical and may vary with the type of bait base used. For instance, baits of high-moisture content are always consumed in greater amounts (by moist weight) than are grain-type baits, thus the amount of toxicant can be reduced proportionately. Whole grains, if formulated with the hulls intact, may have to be formulated at a slightly higher rodenticide concentration, since some toxicants may be lost when the rodents remove the hull before consuming the kernel. If a bait is designed for more than one rodent species (i.e. Norway rat, black rat and house mice), the rodenticide concentration is usually dictated by the least-susceptible species.

3. Adherents for Rodenticides or Binders

It is normally desirable to include a binder such as an edible vegetable oil in most bait formulations. The binder serves two main purposes:

a) Firstly, where the bait base contains course particles such as whole grains, the binder assists in maintaining a uniform dispersion of the rodenticide in the bait and prevents it from settling out.

b) Secondly, the binder greatly increases the safety of bait mixing by keeping a toxic dust from forming during the mixing operation.

The binder should be thoroughly mixed with the bait base, so that when the rodenticide is added it adheres immediately to the bait particles. Alternatively, the rodenticide may be slurried with or dissolved in the binder before mixing with bait base. Oils are usually included in bait at a 2 to 5% concentration. Water may also be used as a binder at a much higher concentration (50 to 100%), achieved by soaking the bait base as required. Paraffin wax may also be used as a binder for anticoagulant baits, usually at a concentration of 20 to 40%. The bait is mixed with melted wax and either cast directly into blocks or pellets, or into sheets which are cut up into blocks before the mixture is set hard. Since anticoagulants are not heat-stable it is important to mix the bait with melted wax at the lowest possible temperature. Wax block baits are sometimes found to be particularly convenient for use against rodents in fields and plantations.

Binders generally have secondary effects upon the efficacy of the formulation. Edible oils tend to increase the palatability of the bait slightly and water usually increases it markedly. If the oil is rancid, however, the palatability of the bait is impaired. Water accelerates the growth of mould and it is advisable to replace the moist bait daily. Paraffin wax gives the bait partial protection against attack by insects and mould and prevents it from being washed away by rain, but tends to reduce palatability.

4. Attractants

Apart from edible oils and water, only sugar, at a concentration of about 5% is well established in improving the palatability of bait to commensal rodents. It does, however, increase the attack on the bait by ants. additives, such as molasses, meat meal or fish meal are not generally found to increase the attractiveness of bait, though they may do so in some cases. Artificial flavourings such as spices and essential oils are of extremely doubtful value and are generally more likely to have repellent than attractant effects. There is no magic ingredient to guarantee good bait acceptance and it is best to rely upon an intelligent choice of good basic ingredients.

Research is going on in the development of species-specific scent compounds that may prove to be highly attractive to rodents. This class of compounds is called pheromones, and these are normally produced by a number of living creatures to aid in species recognition and sex attraction. These are usually hormone-associated compounds that have smell. Rodents are known to secrete such compounds. They are known to be used to denote the reproductive state of female rodents and may also assist in the recognition of related members of a particular rat tribe, to assist in interspecific identification, and to mark animals' territories.

5. Bait Preservatives

Paranitrophenol at 0.25% or dehydroacetic acid at 0.1% may be useful to stop bait going mouldy in the warm, humid conditions of tropical agriculture. As they reduce the palatability of the bait somewhat, they should not be used unless experience has shown that they are necessary. As has been mentioned earlier, paraffin wax has a more marked preservative effect. Zinc phosphide and the anticoagulant pindone have insecticidal properties. Insect damage to baits is rarely a great problem and, as a result, there is no established role for insecticides as bait additives.

6. Colored Dyes

All rodenticidal baits should contain colouring matter, usually a dye. There are a number of reasons for coloring bait, but the two most important benefits are to help prevent accidental human consumption through mistaken identity, and to reduce the hazard of using rodent baits mistakenly for livestock feed.

Reputable manufacturers invariably include a suitable dye in all forms of rodenticide offered for sale unless the rodenticide has a strong natural color. Blue or black dyes are popular because these seem least likely to be confused with food, though a red dye is used occasionally. A green dye is sometimes thought to have value in protecting bait from granivorous birds or from interference by unauthorized persons. The presence of a dye in the rodenticide is very useful as an indicator to show when the bait has been thoroughly mixed.

B. Bait Formulation and Preparation

1. Calculating the Bait Formula

a) When using a technical ingredient, such as zinc phosphide (100%), calculations are straight forward. To prepare a 2% concentration of finished bait, simply add 2 kg of zinc phosphide to 98 kg of bait ingredients.

b) When using concentrates, the rule to remember is to divide the percent of the concentrate by the final concentration desired. The answer obtained will be the total number of parts of bait ingredients needed. Simply substract one part for the concentrate and the remainder will be the bait ingredients.

Examples:(i)a 0.5% concentrate, final mix to be 0.025%
0.5/0.025 = 20

Mix 1 part of concentrate with 19 parts bait

(ii)Racumin a 0.75% concentrate final mix to contain 0.0375%

0.75/0.0375 = 20

Mix 1 part of concentrate with 19 parts bait

2. **Methods**

We will discuss the methods of preparation of zinc phosphide and Racumin baits as these are the only acute and anticoagulant registered poisons in Pakistan.

a) The proportion of the 2% zinc phosphide rat-cake are:

48% flour (atta)
48% broken rice or wheat or maize
2% zinc phosphide
2% cooking oil (vegetable oil)

A sample formula for field use is:

2.4 kg flour
2.4 kg rice, wheat or corn
100 gm edible oil
125 gm zinc phosphide (contains only 80% active ingredients)
Plus enough water to make a stiff dough.

1) In a clean container, bucket or mixer, place the flour and grain and mix well.

2) Add the zinc phosphide to the mixed dry ingredients and mix until the mixture is an even grey color.

3) Add the edible oil and mix well.

4) Slowly add the water and mix until a stiff batter is formed.

5) Place the bait on a smooth surface and roll flat till one centimeter thick. A wooden form and a piece of pipe or round wood can be used to ensure rapid rolling and uniform thickness.

6) Then using a knife, cut the flattened bait into squares about the size of a five paisa coin.

7) Place in the sun to dry for 2-3 days, turning occasionally. Protect from dew and rain.

8) Store in a cool dry place by packing in plastic bags. The sequence of mixing the bait is very important. Zinc phosphide reacts slowly with water to release the poison gas, phosphine. By adding the oil to the dry grain and zinc phosphide mix, the oil coats the zinc phosphide particles and reduces the contact of the water with the poison.

b) Racumin: To prepare a Racumin bait use fairly clean broken rice, cracked wheat or cracked maize. Place 19 parts of the grain in a clean container for mixing. Add just enough edible or cooking oil to lightly coat the grain. When the two are mixed, continue stirring whilst slowly adding the one part of the Racumin master mix, a light blue powder. Mix till the grain is evenly coated.

1) A sample formula for field use is:

4,700 g broken rice
50 g edible oil
250 Racumin concentrate

BAIT MATERIALS: HANDLING, STORAGE, AND GENERAL SAFETY PRECAUTIONS

By Iftikhar Hussain

We know that most of the toxic chemicals and materials used in vertebrate pest control are potentially harmful to man, for he is also a mammal. Special precautions must be observed to ensure the health and well-being of those who are involved in any way with handling vertebrate pest control materials and in carrying out pest control operations.

A. Safe Bait Mixing

The main risks to be guarded against when mixing poison baits are accidental skin contact with the rodenticide and inhalation of toxic dust. The wearing of rubber, PVC, or disposable gloves is generally quite sufficient to prevent skin contact. Simple and effective "gloves" can be made by encasing the hands in small plastic bags that are tied at the wrist. They can be discarded after use. To avoid the spillage or the inhalation of dust, protective outer clothing and a dust mask should be worn. Accidental skin contamination should be washed off at once, and non-disposable gloves should be thoroughly washed inside and outside after use. It is a good general rule to wash hands and any exposed skin before eating, drinking or smoking and after work.

Fig. 1. Wear gloves and a dust mask when mixing baits.

Addition of a binder to the bait base before mixing in the rodenticide is a useful way of suppressing dust. Baits are well mixed in a well ventilated room or in the open air, but draughty or windy conditions must be avoided. Small amounts of bait, upto about 2 kg, can be safely mixed in a bucket with a stick, bamboo spatula or a large spoon. Larger quantities should preferably be mixed mechanically in a sealed vessel such as a seed dressing drum. Fragile or fresh bait materials can be mixed by tossing them lightly with the rodenticide inside a closed plastic bag.

B. Identification of Poisons

When using a hazardous compound, be sure of its proper identification, especially if it is no longer in its original packing. Check the concentration of active ingredient so that proper proportions are used to give the correct concentration in the final bait preparation.

C. Disposal of Containers

At no time and under any circumstances should containers that have been used for toxic compounds be used for other purposes. Such empty containers must be broken, crushed, buried or burned to prevent their reuse. If buried they must not contaminate sub-soil water. If burned, stay out of the smoke, for many pesticide vapours are themselves highly toxic.

D. Protective Clothing

If dust is generated when a bait is mixed with toxic compound, provision must be made to avoid dust inhalation. The use of a dust filter mask or a cloth mask is imperative. Also dusty clothing must be changed each day for clean clothes. The most critical time for protective measures is when the concentrated pesticide is added to a bait mix. At this time the operator should wear a dust mask and gloves.

E. Warning Colouration of Baits

Vertebrate pest control baits, by their nature, are attractive food sources. They would be ineffective if they are otherwise. One method of helping to avoid accidental feeding is the use of a warning colouration. In many parts of the world, e.g. Bangladesh, bright colours like red and green are warnings that the material is harmful. In Pakistan, cooked rice must be avoided. The colours recommended in Pakistan are black, blue, or grey.

Racumin, a chronic poison, comes already coloured blue. Zinc phosphide baits after mixing come out grey in colour. Other baits can be deliberately coloured black by using lamp black or powdered charcoal, or a blue textile dye can be added to the mixed bait. The colours warn people, but do not effect their acceptance by rats, which are colour-blind.

Birds are a different matter, since they see colours well. When using poison baits against birds, colouring the baits may repel them. For birds, a natural bait colour is important, and bait security becomes a problem of major safety concern.

F. Bait Stations

All bait stations must have some marking, to warn people of their contents. This must be done in national language or preferably emphasized with pictorial symbols such as a skull and cross bones.

G. Bait Placement

When controlling field rats, placement of bait must be done carefully so as to avoid accidental poisoning of livestock or people. Never place bait stations or baits on footpaths or roads. They are most likely to be found by domestic animals or to be stepped upon. Place them to one side of the path or field embankment and in the grass or crop so they are hidden as much as possible. Another advantage of hiding bait is that it reduces theft, and the possibility of stolen baits falling into the hands of uninformed people. Rodents who seek their food largely by smell will find such concealed bait easily.

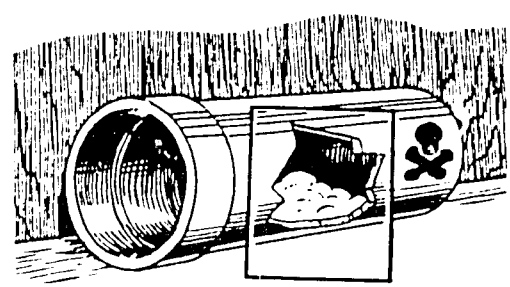

Fig. 2. Bait station.

It is a good rule to keep the bait points numerous and small, rather than few and large. In this way risk of an animal eating a large dose at any one time is restricted.

H. Dead Rats

All dead rodents that are found during the course of the treatment should be picked up to keep carrion-eaters from the risk of secondary poisoning. The operator should recover all residues of bait at the end of the treatment. These should be burned or deeply buried. This precaution is, of

course, not required where permanent bait stations are used and where access by non-target animals can be prevented. In field treatments it is often safe to allow bait residues to decay naturally.

I. Bait Mixing Utensils

When possible, reserve special spoons, ladles, pans and buckets to be used only for mixing bait. Their use for any other purpose may cause accidental poisoning. Also all containers and utensils used in bait mixing must be thoroughly washed after use to avoid any subsequent problems when handled. They must be stored in the same place where poisons and baits are kept.

J. Washing Up

Every person after mixing up, handling or using bait should wash his hands and any other part of his body that has come in contact with bait. Always wash hands before smoking or eating.

K. General Information for the Public

When using bait in a new area, try to inform everybody in the locality about the presence of bait, and that it is dangerous to touch or consume. At the same time indicate the safety precautions to be observed when such bait is being used. Make sure that each bag or parcel of bait has a label with some information about the action of the bait.

L. Safety Precautions on the Use of Fumigants

Because fumigants produce poison gasses which can more easily be accidentally inhaled, they must be used with special care. In the field, fumigation must always be done by a team of two people. Open the fumigant container, and then quickly close it after the proper amount of the fumigant has been withdrawn. The applicator should always stand upwind of the fumigation site so the fumes blow away from him. It is prudent to hold one's breath when doing both of the above. Stop fumigation if either party feels dizzy, and do not carry out fumigation for long periods of time.

Be very careful if any fumigation is done in or around buildings, as well as rat holes that may have more than one opening. If great care is not taken, adjacent living spaces may be accidentally fumigated with serious results. When pumping cyanide powder into a closed space or a rodent's burrow, remember that the pressure which builds inside the confined burrow space will force the gas to find any small leaks. If the pump nozzle is not well sealed around the entrance to the burrow, the gases can escape backwards into the face of the operator.

When using fumigants based on the generation of phosphine gas, such as aluminium phosphide tablets, (marketed as Delia or Phostoxin) there is also a hazard from fire, because phosphorous is highly inflammable in most chemical forms. If a large number of tablets are put together and accidentally struck by some metal object or heated by undue friction, there may be spontaneous combustion.

M. Medical Information

Medical information on the treatment of accidental effects of all poisons used must be at or near the site of use. This should be in the hands of the local responsible officials as well as local doctors. They should be well aware of the toxic compounds used and the symptoms from their poisoning and treatment measures which are appropriate.

N. Safe Storage

Technical grade rodenticides, concentrates and batches of prepared bait should be stored under lock and key and labelled with the name and concentration of the active ingredient. The storage site should be well ventilated and dry, and should be as cool as possible. Baits, in particular, must be stored away from strong smelling chemicals like insecticides so they will not pick up strong odours that may repel rats and render the bait ineffective. The store should be kept clean and tidy. Proper account kept of all rodenticides received and issued.

BAIT APPLICATION METHODS AGAINST RATS IN CROPS

By Abdul Aziz Khan

A. Introduction

For any field rat control programme, the kind of bait, mode of formulation, time and method of application are integral parts of the success or failure of the programme. Also, these criteria must fit into the farming systems and socio-economic construct of the farmers community.

There are certain misunderstandings and traditional beliefs which should not be adopted or practiced: 1) one of the most common is the addition of ground glass to rat bait, the idea being that the glass will lacerate the stomach and intestine of the rat, causing death by internal bleeding. Ground glass is harmless to rats and will not kill the rats as advocated, 2) another traditional belief is that the addition of cement or plaster of paris to rat bait will result in the swallowed food hardening in the stomach of the rat, and that this blockage will cause death. This will not harden in a rat's stomach since it is too acid an environment for such a chemical reaction and 3) another common bait/poison fallacy is that, "if a little poison is good, then a lot more is better". The use of more poison than is required inevitably cause bait refusal and a poor kill because of bait shyness. Also, this will be expensive and dangerous.

B. Bait Placement Techniques

It is essential that bait placement techniques and schedules are worked out according to the agronomic practices of field crops. In this chapter, bait application methods in paddy, wheat and sugarcane will be described.

1. Paddy

In paddy the treatment of the fields begin 3-5 weeks after the nursery plantation. Loose grain bait of anticoagulants packed in polythene bags (100 g) are placed on the field dikes or bunds (low embankments demarcating the fields) every 15 m when field size is 0.4 ha. or one bait point halfway along each bund and one at every intersection between bunds when field size is smaller, keeping the average distance between bait points about 10 m. Treatments with three weeks interval are made, replenishing the first treatment after 3-4 days and the third treatment being done about 2 weeks before harvest. Before placing the polythene bait bags on bunds, these are slit open with a knife. The polythene bags give the anticoagulant baits adequate protection from the monsoon rains and heavy dew. Each anticoagulant bait point in the field is marked by fixing a number flagged stick in the soil. This makes successive treatments at the fixed bait points easier.

Loose grain bait of zinc phosphide and other acute poisons are applied in the similar way as of anticoagulants. At each bait point 10 g of the bait is placed which is checked and repeated twice at an interval of a month. Loose grain baits may be attractive and hazardous to birds, however, so they should be placed into burrows or bait containers wherever possible.

"Rat cake" bait of zinc phosphide, or other acute poisons (bromethalin) are applied on the bunds, 2-3 pieces at each bait point. Placement procedure and time table is the same as in case of anticoagulant baits.

2. Wheat

Baiting can be conducted in wheat fields about 6-8 weeks after sowing. Anticoagulant baits are applied in 100 g polythene bags, slit open in the middle, one bag each being placed on the bunds halfway along each bund and one on the intersection of the bunds. Because of the rodent burrowing activity inside the fields, the baiting is done inside the fields as shown in Fig. 1. Treatments are made with one week interval and baits replenished where it is required. "Rat cake" bait of zinc phosphide and other acute poison is applied on the field bunds after every 15 m interval or halfway along each field bunds and at every intersection of the bunds. Two to three pieces are placed at each bait point. In addition to this, treatments are made inside the fields by "spot baiting". The spot baiting is carried out by walking 3-4 meters from the intersection of bunds and then making a transect inside the plots (Fig. 2). The active and open burrows are treated along the baiting lines. In each field, 3 such lines are made and baited. Inside the fields the bait points are marked with numbered flagged sticks 1.5 m high. This makes easy the successive treatments at these points.

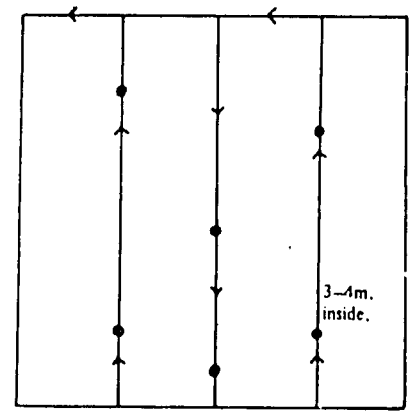

Fig. 1. Spot baiting inside the fields with Zinc phosphide at wheat flowering time.

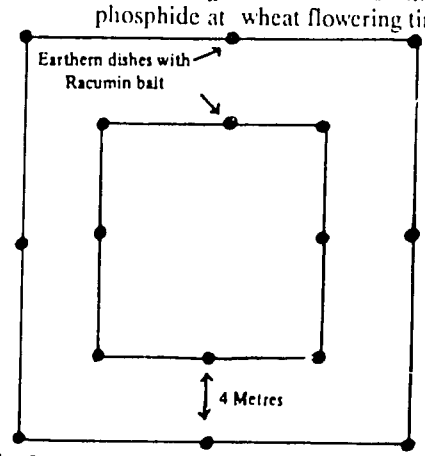

Fig. 2. Placement of Racumin bait inside the fields and along

3. Sugarcane

Baiting in the sugarcane fields is carried out almost the same way as in wheat plots except that only one baiting line instead of three are established in the middle of the fields (Fig. 1 & 2). This is extremely difficult. Anticoagulant (loose grain & wax blocks) and "rat cake" of acute poisons are applied on the bunds and inside the fields after every 10 m intervals. Baiting is conducted with a one week interval. Some variations are adopted according to the size of fields. An alternative is to search out the areas of rat activity (cutting stems, etc.) or burrows and bait at these sites.

4. Treatment of Open Burrows

Treatment of open burrows of *Meriones hurrianae* with different rodenticidal baits is done by "spot baiting". Spot baiting means either putting the bait (rat cake) directly into the burrow or placing the bait (loose grain, pellets and rat cake) on left or right side of the opened burrow. *Meriones* can be serious pests in barani wheat, pulses and groundnut fields.

C. Use of Bait Stations in Crops

All rodent baits are susceptible to damage by moisture, from wet ground, dew, or rain. Rats do not like damp and spoiled bait. Therefore, for effective control, bait protection is important which is done by using various kinds of bait stations (Fig. 3). Besides protecting the bait from adverse weather, their other functions are as follows:

1. To minimize the risk of accidental feeding on the bait by non-target species and domestic animals.

2. To carry a warning on the cover or body of the station. This will protect the public from accidents by informing them about its contents. Use national or regional language for this purpose.

3. In a sustained baiting programme, the bait is regularly replenished freshly and this is possible only through the use of bait stations.

D. Key Features for Sustained Baiting with Anticoagulant Rodenticides

1. Because of its gradual action and the absence of risk from bait shyness developing, anticoagulant baiting can and should begin shortly after or even before any rat activity is evident, if expected.

2. Baiting in growing crops, such as rice, should be continued against field rats until grain heads are fully developed and hardened, which is approximately two weeks before the harvest in most situations. If bait consumption remains high during this period, baiting can also be continued. During control campaigns bait consumption generally increases as more and more rats invade the fields from the surrounding unprotected crops. It then usually declines sharply when grains mature.

3. Excess bait must be available at all times so that rats consume bait regularly over several days. This will also help to decrease the effects of competition of the food source.

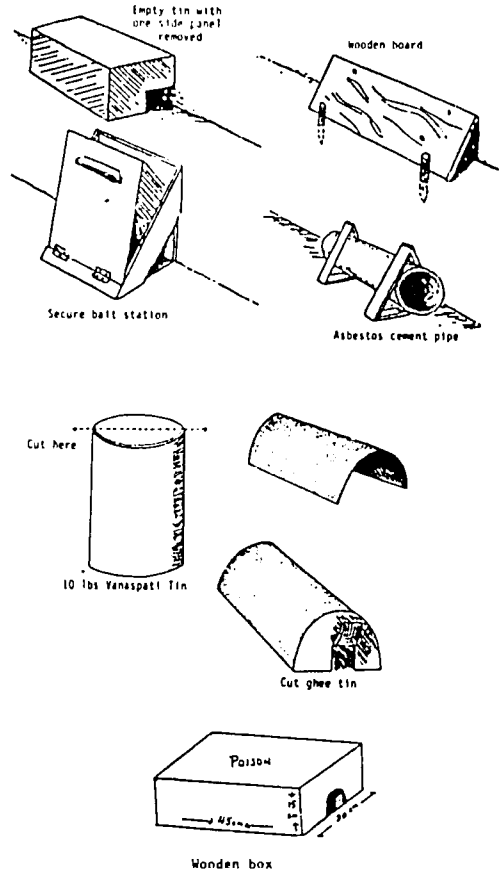

Fig. 3. Bait stations for the use in stores, crops, poultry farms.

4. A wide variety of bait materials can be used, including most forms of husked rice. Highly polished rice or whole maize kernels should be avoided as the toxicant does not stick well to such surfaces. Moreover, rodents tend to discard the seed coat of maize and eat only the starchy contents.

5. Generally, in sustained baiting with anticoagulants, mouldy or fermented baits are avoided by rodents. Such defects obviously reduce consumption of the bait and increase the cost because replenishment with fresh bait becomes necessary.

6. Placing bait in suitable bait stations or placement of the bait in plastic bags are worthwhile practices, to protect the baits from bad weather and damp ground (excessive ground dew).

7. The maximum success with the use of anticoagulants depends upon the cooperation of neighbouring farmers. A cooperative effort is an essential element in controlling field rodents with anticoagulants due to the mobility of these pests.

8. All of the anticoagulant rodenticides being commercially marketed in different parts of the world can be used effectively for field rodent control or in grain storages.

BAIT APPLICATION METHODS IN GODOWNS, SHOPS AND POULTRY FARMS

By Abdul Aziz Khan

A. Introduction

Poison baiting is one of the cheapest, and most effective method of controlling rats on a large scale However, in food grain stores and shops when using the more toxic poisons certain precautions must be taken. The success of poisoning depends largely upon the choice and skillful placing of baits and other poison formulations such as tracking powders and liquid baits.

B. Godowns and Shops

Generally two types of poisons are used against rodents in food storage areas; i) acute or single dose and ii) chronic or multiple dose. Zinc phosphide (acute), coumatetralyl (Racumin), and brodifacoum (Klerat) are the only registered rodenticides available in Pakistan. The acceptance of baits made from these two kinds of poisons depends upon a variety of factors. Rats living in a store containing large amounts of spilled grain normally will not eat the poison baits because of their preference for their regular diet. The following procedures are normally adopted to control rats in the grain storages with varied conditions of infestation and location.

1. In godowns where heavy rodent infestations are recorded, use 5 or 10% zinc phosphide tracking powder to knock down the population quickly. This tracking powder should be used inside protective wooden bait stations, or inside asbestos or PVC pipe bait stations (45 cm long, 7 cm diameter) or on steel trays (1 cm deep, 20 cm long and 15 cm wide). These bait stations or trays are placed along the walls at an interval of every 10 to 15 m. If the godowns are big, place these bait stations in the middle of the godowns beside the concrete pillars. This operation is conducted for 3-4 days only and then the zinc phosphide powder is replaced with 0.75% Racumin tracking powder. The use of this chronic poison will help in the total reduction of the rodent population in any particular godown. Before replacing Racumin powder, clean all the bait stations from zinc phosphide powder. It is difficult to kill 100% of rats with zinc phosphide because of bait shyness. Tracking powder of zinc phosphide can be made easily by mixing it thoroughly with Fuller's earth (Multani Matti). Mix in a pharmaceutical tumbler or in a 2 kg plastic bottle with a screw cap in the ratio of 1 part zinc phosphide to 9 parts Fuller's earth by weight. Mix this for at least 15 minutes. Take necessary safety precautions while mixing.

2. In godowns where the infestation is moderate or low, it is only necessary to use 0.75% Racumin tracking powder in the bait stations or on the steel trays as indicated above. In the bait stations or on the trays, spread smoothly about 25 g of the powder. Check after 3-4 days and replenish the powder if there is evidence that it has been taken up by the rodents on their fur. When no fresh foot prints are seen on the powder, the rodents are under control. If foot prints are seen continue the operation.

3. In our experience in Pakistan, grain baits with zinc phosphide (2%) and Racumin (0.0375%) or other chronic poisons (Warfarin) are poorly accepted by the rats in the grain godowns. This is because of widespread spilled grain around the stacks of bags. Damp baits, such as fruits, are attractive to rats even when they refuse dry grain baits, but they deteriorate quickly due to moulds and bacteria which rats do not like to eat. However, you can use Racumin grain bait (0.0375%) in residential areas peripheral to the godowns to check the migration of rats into the central storage area, especially when the Indian gerbil (*Tatera indica*) is present.

4. Most godown rats will drink water and the use of water- soluble anticoagulant baits, i.e., poison which will dissolve in water, has been very successful in Pakistan in controlling rats in the godowns. Racumin 8% pro-solution is available from which ready-to-use liquid bait can be made. This can be used in automatic poultry water drinking dispensers and placed in the godowns about every 10-15 m at suitable places. These dispensers are checked after every 2-3 days for any replenishment. Freshly prepared liquid baits deteriorate after a few days. The chances of success with liquid bait can be improved if the rats' usual water supply can be cut off. This may be done by improving drainage around the stores and by cutting grass and low vegetation in order to reduce dew formation. Better control is achieved in hot, dry conditions.

C. Poultry Farms

Rat infestations on poultry farms can be controlled or excluded by using traps, chemicals, making sheds rat-proof and improving sanitation conditions. Each method has its merits and demerits. One should understand that to kill some rats is simple, but controlling a rat problem requires trained personnel. However, there are certain control methods which can be applied successfully as a result of which economic losses are minimized. Here only chemical methods will be described.

1. Use of Poison Baits

a) Acute Poison Bait

Zinc phosphide bait can be used when the rat population is high and the damage to the eggs is severe. Zinc phosphide bait is inexpensive and one can achieve a quick reduction in the population. It is generally used at a strength of 1 or 2%. Loose grain bait of zinc phosphide can be used only in areas where layers and broilers are kept in cages or in areas where stores are located. Use this bait in the protected bait stations and place these stations along the walls at intervals of 15-20 paces. In each bait station put 100 grams of bait. This bait can also be used to kill rats in open burrows whenever they are found inside or outside the poultry sheds. For each burrow place one teaspoon full of bait well into the hole. This bait should not be used in the chick breeding and feed mill areas because of hazards to the birds.

b) Chronic Poison Bait

Use these baits in all areas of the poultry farm in the bait stations as earlier described for zinc phosphide bait. To attain maximum control the bait should be replenished and checked after every third day. Within 4-6 weeks the rat population will be greatly reduced. To control the invading rats from adjoining farms, keep the bait stations functioning and checking them every 3rd week. Racumin (0.0375%) or other anticoagulants baits can be used.

c) Poison Tracking Dusts

The other useful way of controlling rats is the use of poison tracking powders. The method of control takes advantage of the instinctive grooming behaviour of the rodents. After picking up poison dust on their feet and body, rats and mice while grooming ingest lethal amounts of poison. This method is useful in those situations where the rats avoid traps or refuse to eat the grain bait. The dusts of acute poisons should not be used on the poultry farms because of danger to animal health. Only anticoagulant dusts should be used. Racumin tracking powder (0.75%) is locally available and can be used in the protected bait stations. In each bait station, 25 to 50 grams of the dust is applied. These should be placed along the walls every 8 to 10 meters. Tracking powders can be applied with a large spoon. Check after every two weeks and replenish as needed. Keep tracking powder stations in operation throughout the year if you suspect migration from neighbouring farms.

FIELD EVALUATION OF RODENTICIDE BAITS AND CONTROL PROGRAMMES

By Abdul Aziz Khan

A. Introduction

In a fully operational rodent control programme a number of varying and interacting factors are involved, such as (1) social attitudes, (2) manpower, and (3) methods and materials. The planning and evaluation of the first two factors is the job of sociologists and economists while the third factor is handled by an experienced biologist to determine the success or failure of any programme. Particular emphasis is given to the need for monitoring not only to measure success, but also to identify those elements of a programme that contribute to or detract from its success. Evaluation and monitoring are essential management tools to ensure that the programme will achieve its objectives. Generally, essential components of a rodent control programme should be:

1. Objectives and planning
2. Setting priorities
3. Evaluation and monitoring
4. Programme improvement and publication of the results

When planning, we must answer these questions:

a) Where are we now?
b) Where do we want to go?

What kind of information do we get to determine a and b? These are as follows:

i) What levels of rodent damage or infestation exist before the institution of a programme.
ii) What levels should be existing if the objectives of the programme are to be achieved.
iii) What actions should be taken to make the plan a success.

To answer these questions, there is a need for detection or evaluation of rodent control programme for which the following three questions are to be asked:

1. What methods are currently used to detect the need for control and act as a trigger for action?
2. What detection methods should be used?
3. What actions are needed to improve the existing methods and to introduce new methods?

B. Evaluation Techniques

The evaluation of the success of any rodent control programme in major crops can be assessed by:

1. Snap-trapping
2. Rodent activity index
3. Counting damaged tillers or canes
4. Crop yields

For comparative and economic reasons, similar data should be obtained from untreated areas. In the determination of efficacy of any rodent control materials and methods, snap-trapping or kill trapping contribute negatively to the efficacy data as these two are tools of controlling rats. Therefore, the other three techniques are used in the development of data of the programmes. Generally, these evaluation parameters are recorded before and after the rodent control operations, which are described for application in wheat, paddy and sugarcane.

1. **Snap-Trapping**

Snap-traps are set along straight trap transect lines on the treatment and control areas for three successive nights. The traps are baited with buttered chapatti and are set at 15 pace intervals (approx. 15 m) on the trap lines in the evening and picked up in the morning before sun rise. The first trapping is conducted in the week before the first bait placement and again one or two weeks before harvesting the crops. The trapping data for each rat species are pooled together for each crop and efficacy of different rodenticidal baits or treatments is evaluated by using the formula:

$$\text{Percent Reduction} = 100 - \left[\frac{\text{No. of rats trapped on the treatment fields}}{\text{No. of rats trapped on the control fields}} \times 100 \right]$$

The abundance of rat species is determined by trap success which is calculated as follows:

$$\text{Trap success} = \frac{\text{No. of rats trapped}}{\text{No. of trap nights}} \times 100$$

2. **Tracking Activity**

Tracking activity index is utilized as an evaluation technique in majority of the field trials. This gives an index of relative rodent activity/population of rats and calculated as follows:

$$\text{Activity index} = \frac{\text{No. of positive plates}}{\text{Total No. of plates laid}} \times 100$$

The procedure involves the use of tin sheets (plates) or vinyl tiles of approximately 25 cm square in size. The sheets are half coated with a paint brush (10 cm) by spreading a prepared paint made from lamp black colour mixed with coconut oil (to prevent flowing) or cyclostyling printing ink. The inked sheets are placed on activity index tracking lines at an interval of 15 m. Plates with rodent tracks on the unpainted half are recorded each morning as positive or negative if there are none. Tracks are wiped off from the uninked portion after taking the observations and then placed freshly in the evening. Tracking activity is recorded for three nights. The first rodent activity index is recorded before the first bait placement and the last observations are recorded two weeks before the harvest of the crops.

3. **Burrowing Activity**

Burrow activity is also utilized as a census technique in fumigation trials against *Nesokia indica* and baiting against *Meriones hurrianae*. The procedure involves closing all active burrows with soil and then recording new and reopened burrows for the same length of time both before and after toxicant treatment. Burrows are numbered and recorded on the data sheet. The success of the treatments is calculated using the following formula:

$$\text{\% reduction in animal population} = 100 - \left[\frac{\text{Post-treatment census data}}{\text{Pre-treatment census data}} \times 100 \right]$$

4. **Damage Assessment**

Counts of damaged and undamaged tillers, stems and canes are made on the treated and untreated fields along a transect line. In paddy and wheat the counts are made of hills at two paces (about 1.5 m) intervals. The first and subsequent counts (monthly) are made before the population/activity record and bait application. About 25 percent of the total number of fields from the treatments and control sites are usually picked up randomly for damage assessments.

In paddy, percent rodent damage to tillers is estimated by using the following formula commonly used in Philippines for nation wide rat damage survey:

$$\text{Percent damage} = \frac{\text{No. damaged tillers} \times \text{No. damaged hills}}{\text{Total tillers in damaged hills}} \times 100$$

In sugarcane fields the damage estimates are made by walking through the fields on a transect line and determining the percent damaged stalks:

$$\text{Percent damage} = \frac{\text{No. of damaged stalks}}{\text{Total No. of counted stalks}} \times 100$$

In cane fields the counts can be made after every two months before taking data on rodent activity and placement of baits.

In all crops the relative percent reduction in damage after treatment is calculated as follows:

$$\text{Percent reduction} = 100 - \left[\frac{\text{No. of damaged tillers, stems, canes on treated fields}}{\text{No. of damaged tillers, stems, canes on untreated fields}} \times 100 \right]$$

5. **Yields Assessment**

The yields of produce of these crops are unhusked rice (paddy), threshed wheat and stripped canes. The yield data are obtained from those fields from where rat damage estimates are obtained. For paddy and wheat, the data are obtained directly from the farmers when the grains are still on the farmstead. While for sugarcane, the yields are determined and obtained at weighbridge of sugar mills. All yields are obtained in metric tonnes.

C. **Data Analysis**

Standard statistical methods such as "students 't'" test, analysis of variance and other test analyses are applied to analyze the data on these parameters wherever required. For economic analysis of the programme, the current commodity support prices and production statistics are used. Current market prices of rodenticide concentrates or baits registered for use in the country and ex-Karachi FOB costs of unregistered are considered to determine the cost-effectiveness of preventing rat damage to various crops by using different rodenticide baits.

FUMIGANTS, THEIR PROPERTIES AND APPLICATION

By Joe E. Brooks

A. Properties and Application

Fumigants are used to kill rodents and their ectoparasites living in inaccessible areas in buildings, ships or in burrows in the soil. Fumigants are quite dangerous, both to the persons using them and to other humans or animals in the immediate area. Experience and skill are required therefore in their application. Fumigants most commonly used against rodents are calcium cyanide (to produce hydrogen cyanide), methyl bromide, chloropicrin and aluminium phosphide (to produce phosphine). More rarely used are carbon dioxide, carbon monoxide and sulfur dioxide.

Fumigants having a molecular weight less than 29 tend to rise to the top of burrow systems when used in the soil. Factors that can be important in burrow fumigation are the moisture content of the soil and its particle size. Hydrogen cyanide, methyl bromide and hydrogen phosphide are extremely toxic gases and great caution must be taken to avoid inhaling them when fumigating burrows, confined spaces or commodities under gasproof tarpaulins. Some characteristics of commonly used fumigants are given in Table 1.

Table 1. Some Characteristics of Rodent Fumigants

Fumigant	Chemical structure	Molecular weight	Physiological action*	LD_{50}(rat) mg/litre	Flammable
Hydrogen cyanide	HCN	27	C.A.	0.4	Yes
Carbon monoxide	CO	28	C.A.	(0.35%conc)	No
Hydrogen phosphide	PH_3	34	I.	0.8	Yes
Carbon dioxide	CO_2	44	S.A.	(20-30% conc)	No
Sulfur dioxide	SO_2	64	I.	1.6	No
Methyl bromide	CH_3Br	95	I.	3.6	No
Chloropicrin	CCl_3NO_2	164	I.	2.0	No

* C.A. = Chemical asphyxiant; S.A. = Simple asphyxiant; and I. = Irritant.

1. Calcium cyanide

Calcium cyanide $Ca(CN)_2$, is most frequently used in outdoor operations (it should not be used closer than 3 m to buildings); it is greyish-white and available in a granular or powdered form. The granules or powder are blown or spooned into a burrow and hydrogen cyanide (HCN) is liberated when they come into contact with moist air or soil. Hydrogen cyanide is lighter than air and the gas accumulates in all the upper parts of the burrow network; thus all holes must be sealed quickly. Calcium cyanide is usually blown into burrows using a special commercially available pump. The hose is inserted into the burrow opening and soil packed around it. Five or six strokes are then made with the pump handle, the valve switched to "air" and about 10 more strokes applied to blow the powder further into the burrow system. Entrances into the treated burrow are then immediately closed with soil. A second person should stand by with a stick or other weapon, ready to kill any rats that bolt from the burrow system. Holes reopened in a day or so will indicate whether some rodents have survived, and the burrow system then should be retreated.

Gassing with cyanide should always be done by more than one operator, for HCN is quick-acting and a person working alone could become exposed and die without help. Workers using calcium cyanide should carry ampoules of amyl-nitrate as a first-aid measure in case of accidental poisoning. A broken ampoule is held under the nose of the affected person for 30 seconds out of every two minutes and a physician should be called immediately. Death may result from a few minutes exposure to 300 ppm HCN.

2. Methyl bromide

Methyl bromide (CH_3Br), is an odourless, highly toxic gas used in general pest fumigation, mainly indoors for insect control and, occasionally, against rodents. Methyl bromide cylinders with a valve and hose attached are used to fumigate rodent burrows in the same way as hydrogen cyanide. The hose is inserted into the burrow, soil is packed around it, and the valve opened for several seconds, releasing 15-30 ml of liquid methyl bromide into the burrow. The burrow is then closed and examined a day or two later. Methyl bromide should not be used near roots of trees or shrubs, as it is toxic to plants. Hazards associated with using methyl bromide in rodent control operations demand that the work is carried out with care by experienced operators and precautions taken to prevent the liquid material from getting in the eyes, mouth or on the skin. The wearing of gloves is not advised since any liquid penetrating them can become trapped and cause serious burns to the skin. Methyl bromide should not be used at low temperatures (below 2-4^{0}C) as the liquid will not vapourize and the valve on the cylinder may freeze up. Fumigation of ships and warehouses has been conducted but some goods, e.g. flour, may become tainted and should never be treated.

3. Chloropicrin

Chloropicrin (CCl_3NO_2), sometimes known as tear gas, has been occasionally used to drive house mice out of grain storage areas. Mice die even when subjected to a concentration of less than 32 ppm of chloropicrin. Mixed with heavy motor oil, chloropicrin has been suggested as a burrow fumigant for rats and sometimes a small quantity is mixed with methyl bromide to provide an olfactory warning to the person using that gas. Overexposure to chloropicrin produces severe sensory irritation in the lungs apart from severe lachrymatory effect and this chemical is also a strong skin irritant.

4. Hydrogen phosphide

Hydrogen phosphide (PH_3), also known as phosphine, has been used as a fumigant against insects infesting stored products for many years. The gas is liberated from a highly compressed tablet compound of ammonium carbonate and aluminium phosphide. When the tablet is exposed to moisture, it decomposes into hydrogen phosphide, aluminium hydroxide, ammonia and carbon dioxide. A tablet weighing 3 g liberates 1 g of hydrogen phosphide. Hydrogen phosphide is a colourless, poisonous, spontaneously flammable gas, slightly heavier than air, with a sharp garlic-like odour. The odour may not be a sufficient warning, however, to workers accustomed to the use of the gas. The prepared tablet is relatively safe to handle; it is not selfcombustible, but should not be exposed to an open flame. Workers handling the tablets should wear gloves.

Hydrogen phosphide is sometimes used to fumigate burrows of *Rattus norvegicus, Bandicota bengalensis* and *Nesokia indica* in parts of Asia and elsewhere. Normally one or two tablets are placed into each burrow entrance and the openings are then closed with soil. The speed of liberation of the gas in burrow systems is dependent upon both soil moisture and temperature levels but it normally takes several hours to fumigate a burrow.

5. Carbon dioxide

Carbon dioxide (CO_2), has been occasionally used to fumigate cold storage warehouses and corn-ricks against house mice. It was found that CO_2 concentrations of 23% or greater killed wild house mice in less than two hours and that the gas was most easily and economically applied using solid CO_2 (dry ice). Dry ice has been proposed for fumigating refrigerated warehouses where low temperatures must be maintained. The ice is crushed and distributed throughout the room; an electric fan is then used to disperse the gas. Approximately 2 kg dry ice/m^3 of space is needed to give a 15% concentration of gas over 24 hours.

6. Carbon monoxide

Carbon monoxide (CO), from petrol engine exhaust fumes, can be used to kill rats in outdoor burrows. A flexible hose is attached to the exhaust pipe and the other end is inserted inside the burrow. All of the burrow openings are then sealed and the engine run for about five minutes. Precautions must be taken to ensure good ventilation of the vehicle since carbon monoxide might be forced back along the exhaust system and leak into it.

A carbon monoxide cartridge has been developed containing sodium nitrate and charcoal that has proved useful in control of burrowing rodents. It contains 65 parts sodium nitrate and 35 parts charcoal. Another version containing 55 parts potassium nitrate and 45 parts sawdust has also been used.

7. Sulfur dioxide

Sulfur dioxide (SO_2), is a colourless, non-flammable gas with a strong suffocating odour. It is intensely irritating to the eyes and to the respiratory tract. Sulfur dioxide was formerly used to fumigate rat-infested ships but now it is mainly used in the preservation of fruits and vegetables. Sulfur, mixed with potassium nitrate (saltpetre) and a small amount of tallow constitutes the so-called "smoke ferrets"; the smoke produced on burning has been used to make rats run from their burrows when they can be killed by force. This method can also be used for the rapid collection of live rats, needed for laboratory and other experimental purposes, such as the examination of ectoparasites. The use of SO_2 as a general burrow fumigant is not recommended, however.

ECTOPARASITES AND ENDOPARASITES OF RODENTS

By Rafia Rehana Ghazi

A. Fleas

These are highly specialized, wing-less insects in the holometabolous order Siphonaptera, in which the adults of both sexes feed on the blood of vertebrates by means of piercing-sucking mouthparts; the larvae develop on proteinaceous matter. The adults are long-lived, the females lay successive batches of eggs throughout their long life. Most of the 2000 odd species and subspecies habitually leave the host from time to time, this habit eminently fits them to transmit bacterial or rickettsial disease organisms. Fleas are found on mammals of all types, but the majority and the most important species parasitize burrowing or nesting rodents, lagomorphs and insectivores. Some 30 species in the genera *Echidnophaga* and *Hectopsyllus* remain permanently attached to the host as ectoparasites, while the small genus *Tunga* is almost endoparasitic.

1. Basic Biology

A flea's life-cycle has four distinct stages; egg, larva, pupa and adult. The female lays 100-200 eggs in small batches, loosely on the animal host or in animal bedding, cracks of floors and other favoured places. The small white eggs have a shell that protects them from damage, desiccation and pesticides. Within 48 hours they can hatch into flea larvae, which feed on organic matter in soil and debris. The larvae spin cocoons which are very small and sticky, thus attracting dirt which makes them impossible to see. The cocoons lie hidden in cracks and under carpets. While inside, the pupae develop into adult fleas. The total flea cycle can take months; however, under warm and humid conditions, it can be as rapid as 14 days.

The adult flea is strongly sclerotized and laterally compressed. It is ready to feed 24 hours after leaving the cocoon. It can leap with its metathoracic legs to a height of 65 mm and a length of 180 mm e.g. *Xenopsylla cheopis*. Eyes are usually very small or even absent in some species. Upon arrival on the host, the flea inserts its styletto-like paired mandibles (Laciniae) and unpaired epipharynx into the skin. The blood is sucked directly from a capillary blood-vessel. A blood meal is necessary for maturation of the eggs.

2. Common Rat Flea Species Attacking Man

A dozen species, all of which attack commensal rats to a greater or lesser degree and nearly all of the old world origin have become cosmopolitan or are in the process of becoming so, due to association with man, his pets, livestocks and his rodent pests.

Xenopsylla cheopis, the oriental rat flea, is the most important vector of urban plague and murine typhus. It has been distributed to all parts of the world in ships and cargoes, particularly in the second half of the 19th century. It is characteristically found in buildings, parasitizing *R. rattus, R. norvegicus* and other species of *Rattus*.

X. astia, a parasite of gerbils and rats, ranges from Arabia and Iran through India to southeast Asia. Less domestic and a weaker plague vector than *X. cheopis*.

X. brasiliensis is native to all Africa south of the Sahara, but it has spread to all parts of the world. It is an effective plague vector, especially in rural environments, and infests rats not only at the ground level but also in walls and roofs.

Nosopsyllus fasciatus, the northern rat flea is prevalent on rats in Europe, North America and Australia. Presence has been noted on *R. norvegicus* and *R. rattus* in Pakistan. It is a less important vector of plague and murine typhus.

Monopsyllus anisus is a common rat flea of temperate east Asia, extending from China, USSR to Japan.

Leptopsylla segnis, the mouse flea, which probably originated on *Mus* and *Apodemus*, is more abundant on rats than on mice in Egypt, Malta, and Gulf States of USA. It is a weak vector of plague and murine typhus.

There are some more fleas which attack man; these are:

a) *Ctenocephalides felis*, the cat flea. It is also present on dogs and jackals in India. It also occurs on rats and other rodents.

b) *C. canis*, mainly parasitizes dogs and other canidae. Both species of *Ctenocephalides* can transmit disease organisms to man by his domestic pets.

Echidnophaga gallinacea is common in Africa. It is abundant on a wide variety of small mammals and it remains stuck to a single host individual. It plays a minor role in disease transmission.

Investigators have recorded instances of human infestation by European hen flea, *Cerratophyllus gallinae*, the western hen flea, *C. niger*, and the wild-bird flea, *Dasypsyllus gallinulae*. *Hoplopsyllus anomalus*, a vector of plague among ground-squirrels, is also known to attack man. The hedgehog flea, *Synostemus pallidus* is a suspected plague vector. *Stivalius cognatus*, which attacks rats and man, was the most abundant flea in plague focus in Java.

B. Fleas and Diseases

1. Plague

Plague is mainly an infection of wild rodents, caused by the bacillus *Yersinia pestis*. Effective vector species are those in which blood-meals frequently cause blockage, e.g., *X. conformis, X. cheopis, X. skrjabini, Oropsylla silantiewi, Pulex irritans,* and *Ctenophthalmus* spp.

Plague epidemics among animals (epizootics) were first recorded in 1850's among the marmots of Mongolia and Transbaikalia, USSR. Urban plague in cities and towns is transmitted not only by the rodent fleas, *X. cheopis, X. astia* and *X. brasiliensis*, as well as *Nosopsyllus fasciatus*, but also by other cosmopolitan commensal fleas, *Pulex* and *Ctenocephalides*. The number of flea species known to be implicated in plague transmission totals more than 200, with many others suspected.

2. Murine Typhus

This disease is due to *Rickettsia mooseri*. Murine typhus is an infection of commensal rodents. Fleas are associated with murine typhus transmission. Human infection results from contamination from the dried feces and crushed bodies of fleas.

3. Q Fever

The causative organism of Q fever, *Coxiella burnetii* has been found in the flea *Ctenophthalmus assimilis* infesting mole nests in the central Slovakia. These fleas were also found positive for spotted-fever rickettsias which are probably *R. siberica* (agent for Siberian tick typhus).

4. Tularemia

This is an infection of man caused by the bacillus, *Francisella tularensis*. It is present in rodents and lagomorphs. Ticks and fleas are involved in its transmission. It was first found in 1911 in California; by 1938 more than 2000 cases were recognized in America, with 5% death rates.

5. Salmonellosis

This is an enteric disease in rats caused by *Salmonella enteritidis* and *S. typhimurium*, transmitted by the rat fleas *X. cheopis* and *Nosopsyllus* sp.

6. Parasitic Worm Infection

a) Dog Heartworm

This disease is due to infection by microfilariae of nematode worms. The heart worm, *Dipetalonema reconditum*, is transmitted by fleas.

b) Tapeworms

Fleas act as intermediate hosts for three kinds of cestodes, the dog tapeworm and two species of rat tapeworms.

C. Ticks

About 300 species of ticks are blood sucking ectoparasites of vertebrates, chiefly mammals, and nearly all are capable of biting man. Certain species are vectors of important diseases and few are known to transmit human diseases. Cosmopolitan in distribution but numerous in warm countries. Nocturnal in habit.

The body is flattened dorsoventrally, slightly convex dorsally, bearing four pairs of six-jointed legs and a false head or capitulum, consisting of a basal plate, the basis capituli (the shape of which is of taxonomic value) and the mouth parts (hypostome, chelicerae and pedipalps). The hypostome, covered with transverse rows of recurrent, file-like teeth of variable pattern, anchors the parasite to the host. The lateral paired chelicerae are long cylindrical chitnous shafts, they act as cutting organs to permit the insertion of the hypostome.

1. Biology

During the larval, nymphal and adult stages, most ticks are intermittent parasites of mammals and spend the main part of their existence on the ground in areas covered with shrubs. The larvae and nymphs feed on small mammals and the adults on larger ones. Both sexes are blood suckers; only the hypostome and chelicerae enter the wound. The female deposits 100-200 eggs in small batches. Ticks are divided into two large families; the Argasidae or soft ticks, with four genera, and the Ixodidae or hard ticks with several genera. These are more specialized and more highly parasitic, produce more progeny, and infests the hosts more readily.

Genus *Ornithodorus* or soft ticks: Several species of the genus are vectors of local types of relapsing fever throughout the world; the bite causes severe pain and inflammation. The bites of both the nymphs and adults produce hard red wheals which remain painful for 24 hours.

Several species of Ixodidae are injurious to man.

a) Genus Haemaphysalis

The immature ticks are parasites of birds and squirrels, while the adults infest rabbits, hares, cats, woodchucks, chipmunks and rats. It is a vector of tularemia and Rocky mountain spotted fever among animals.

b) Amblyomma Spp.

Amblyomma americanum is an experimental vector of Rocky mountain spotted fever. *A. cajennense* is an experimental vector for yellow fever. *A. hebracum* is a vector of heartwater fever of cattle, and the African tick typhus of man.

c) Dermacentor Spp.

The host for immature forms are small rodents. They transmit rocky mountain spotted fever and tularemia to man.

d) Genus Hyalomma

Species of the genus are parasites of rabbits and burrowing rodents in Africa, Asia and Europe. They transmit African tick typhus to man.

2. **Pathogenicity**

Ticks injure man and lower animals in three ways (1) by the irritation of their bites, (2) by producing tick paralysis through their poisonous secretions and (3) by serving as vectors of bacterial, rickettsial, viral and protozoan diseases.

3. **Human Diseases Transmitted by Ticks**

a) **Rickettsial Diseases**

1) American spotted fever (*R. rickettsii*), vectors are: *Dermacentor* sp; *Haemaphysalis* sp; and *Ornithodoros* sp.

2) Boutonneuse fever (*R. conorii*), vector is: *Rhipicephalus* sp.

3) African tick fever, vectors are: *Rhipicephalus* sp; and *Hyalomma* sp.

4) Russian tick typhus, vector is: *Dermacentor* sp.

5) Q fever (*Coxiella burnetii*), vectors are: *Dermacentor* sp; *Amblyomma* sp; and *Haemaphysalis* sp.

b) **Viral Diseases**

1) Equine encephalitis, vector is: *Dermacentor* sp.

2) Yellow fever, vector is: *Ornithodorus* sp.

3) Lymphocytic choriomeningites, vector is: *Dermacentor* sp.

4) Colorado tick fever, vector is: *Dermacentor* sp.

c) **Rickettsial and Spirochaetal Diseases**

1) Tularemia, vector is: *Dermacentor* sp.

2) Relapsing fever, vector is: *Ornithodorus* sp.

d) **Protozoan Diseases**

1) American trypanosomiasis (*Trypanosoma cruzi*), vectors are: *Amblyomma* sp; *Rhipicephalus* sp; and *Ornithodorus* sp.

D. Mites

The term 'mite' is applied to members of the order Acarina. The parasitic species either cause direct injury to man or transmit human diseases. Species of major medical importance are found in Trombidiformes, Mesostigmata and Sarcoptiformes. The Trombidiformes includes the family Trombiculidae with several species. The Mesostigmata contains family Dermanyssidae and the Sarcoptiformes contain the important family Sarcoptidae. The larvae are known as Chiggers. They are annoying pests and certain species are vectors of the disease 'Scrub' typhus.

The symptoms caused by the attachment and feeding of *Eutrombicula* sp. are itching, increasing in intensity to maximum on the second day. Severe infestation may produce fever and nervous symptoms.

The rat mite, *Ornithonyssus bacoti*, is prevalent in warm countries. It requires four blood meals to complete its life cycle. Its bite produces a vesicular dermatitis with urticaria and subsequent scratching, particularly in children, may cause secondary infections. This mite serves as a vector for the transmission of endemic typhus from rat to rat. *Rickettsia mooseri* (typhi) has been isolated from this mite. *Leptotrombidium akamushi* and *L. deliense* are considered to be important transmitting agents in Pakistan in addition, *L. pallidum* and *L. scutellave* are considered as vectors in Japan. The former is also considered a vector of scrub typhus in southern Korea. Isolations of *R. tsutsugamushi* have been reported from various wild chiggers in various parts of Asia.

Natural infection with *R. tsutsugamushi* was demonstrated from tissues of rodents in almost all the habitats in Pakistan.

The itch and mange mites are of medical and veterinary importance. These minute, globular, white mites have a finely striated integument adorned with bristles. Most of the genera are non-burrowing mites that produce a many layered 'scab' by irritation. The genus *Sarcoptes* causes itch or mange by burrowing into the skin of man and other mammals while the genus *Notoderes* produces similar lesions in cats and rodents.

E. Lice

Lice are small, degenerate, dorsoventrally flattened wingless insects. They are parasites of birds, mammals, and man and comprises two orders (1) Mallophaga (biting lice) and (2) Anoplura (sucking lice). The biting lice are ectoparasites of birds, their mouth parts are adapted for mastication. They never suck blood directly but feed on cuticular material, hair and feathers. The sucking lice have mouth parts for piercing and sucking. The Anoplura comprises of 225 species. The parasitic lice of man belongs to the family Pulicidae and genus *Pediculus*.

Lice are also regarded as vectors of animal diseases, as they transmit diseases among lower animals. Tularemia is spread in rabbits, plague in marmots; bartonella infections in rats and mice; typhus in rats; and the tapeworm, *Dipylidium caninum*, in dogs. Lice are known to play an important role in the transmission of typhus infections. The most common genus found on rats is *Polyplax* sp.

F. Endoparasites of Rodents

Rodents are cosmopolitan in their distribution and they constitute the largest group of mammals. Helminth parasites are commonly reported from these rodents. Adult helminths representing more than 200 genera, with several hundred species, have so far been reported as naturally occurring in rodents.

Helminth parasitic fauna of rodents is dominated by the nematodes. The most common groups of nematodes encountered in rodents belong to the orders Spirurida, Oxyurida and Strongylida. The spiruriods are represented by the genera *Spirura, Protospirura, Gongylonema, Physaloptera, Abbreviata, Rictularia, Pterygodermatites, Seurratum* and others. The Oxyuriods are species of the genera *Passalurus, Enterobius, Citellina, Aspicularis, Syphacia* and others. Species of the genera *Nematospiruroides, Nippostrongylus, Longistrongylus, Longistriata, Heligmosomum* and others represent the *Strongylida*. *Trichinella* and *Capillaria* are also encountered, but to a lesser extent.

Cestodes constitute the second largest group of helminth parasites of rodents. The cestode fauna of rodents is dominated by the hymenolepids and the anoplocephalids. Species of the genera *Hymenolepis, Rodentolepis* and *Vampirolepis* are the main tapeworms encountered. Species of the genera *Inermicapsifer, Mathevotaenia, Citotaenia* and others represent the anoplocephalids. Davanids and dilepidids are found to some lesser extent; these are represented by the genera *Raillietina* and *Choanotaenia*.

The digenean trematode parasites are comparatively few. These represent the family Echinostomatidae where species representing several genera are found. Species belong to the family Notocotylidae, Brachilaimidae, Heterophyidae are reported.

Rodents are poor hosts for acanthocephala, where parasites of few genera have so far been reported. Species of the genus *Moniliformis* are most common.

Several species of helminth parasites are common to both man and rodents. Some are accidental infections and have little public health importance, some occur naturally in numbers of rodents and play a significant part in the epidemiology and prevalence of some of the important human parasites.

The rat lungworms of the genus *Angiostrongylus* are of considerable public health importance as they can be transmitted to man and produce eosinophilic meningitis or cerebral angiostrongyliasis. These lungworms utilize certain molluscs and prawns as intermediate hosts. Human infection occurs when raw or undercooked molluscs or prawns containing infective larvae are ingested.

Nematodes of rodents recorded in Pakistan are:

- *Physaloptera qadri*
- *Pseudophysaloptera sindensis*
- *Aspicularis* sp.
- *Trichiuris*, sp.
- *Protospirura* sp.
- *Rictularia* sp.

- *Pterygodermatites* sp.
- *Streptopharagus* sp.
- *Seurratum* sp.

Cestodes of rodents reported from Pakistan are:

- *Hymenolepis diminuta*
- *H. jacobsoni*
- *H. mujibi*
- *H. nana*
- *Mathevotaenia* sp
- *Raillietina* sp.
- *Catenotaenia* sp.

Trematodes of rodents recorded:

- *Catatropis pakistanensis*
- *Echinostoma bengalensis*

COMMENSAL RODENTS AND ECTOPARASITE CONTROL

By Joe E. Brooks

A. What are the commensal rodents?

With the sole exception of man, the most successful and abundant mammals on earth today are the commensal rats and mice. They would never have enjoyed this success without mans' inadvertent help. Commensal rodents have taken advantage of human transport and trade routes and in this way they spread from their ancestral homes in Asia to all the continents of the world.

What are the commensal rodents? Commensal refers to the fact that these animals live at mans' expense, invading his home, eating his food and damaging his commodities; they are also capable of transmitting diseases to man, who thus derives no benefit from the relationship. Three species of worldwide occurrence are the most important of the commensal rodents: the Norway or brown rat, *Rattus norvegicus*, the roof rat, *R. rattus*, also called the black or ship rat, and the house mouse, *Mus musculus*.

B. Where are they distributed?

The roof rat is primarily a rat of the tropical regions of the world (Appendix 1). Its' ancestral home was probably the Southeast Asian mainland. From there it spread by way of shipping and caravan routes across the Indian subcontinent and into the Middle East. From there it was carried into Europe in the 11th or 12th centuries. Finally, it has been carried by ships to all the continents of the world: North and South America, Australia and into the South Pacific islands. It is still spreading into inland areas in Africa and the Pacific islands.

The Norway rat is primarily a rat of the temperate regions of the world (Appendix 2). Its' ancestral home was the steppes of central Asia, now lying mostly within the borders of the Soviet Union. It spread much more slowly than the roof rat, moving mainly westwards, following the trade routes between China and Europe as they opened up in the 14th through 17th centuries. It didn't reach Europe until early in the 18th century, appearing first in some Baltic seaports and then rapidly spreading throughout Europe in the next 100 years. It was carried by shipping into most of the major seaports of the world during the next two centuries. It remains mainly restricted to seaport areas in much of the tropical world.

The house mouse was originally found in the area between Iran and the Soviet Union, living as a mouse of grassland areas. It has been spread around the world, mainly by ships. It now has the widest distribution of any animal except for man. It lives in the high latitudes of the Arctic, in Siberia, and is found on islands in the Antarctic Ocean. It lives not only in mans' houses, villages, towns and cities, but occurs as a field rodent in many cropland areas.

C. How are they identified?

The identifying field characteristics of the three commensal rodents are given in Appendix 3. Norway rats are stocky, medium to large-sized rodents and the tail is usually shorter than the head and body length. The snout is blunt, the ears relatively short and thick and the fur is coarse, being brownish-grey on the back and whitish-grey on the belly (Fig. 1). The female has 12 mammaries; three pairs in the groin and three pairs on the chest.

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The roof rat is a moderate-sized, slender, agile rat. The black rat, which is a color variant of the roof rat, has a slate-grey to black colored back and a dark grey belly. Although the brownish-grey and the black color variants were earlier referred to as separate subspecies, this is no longer considered to be valid, with both color variants commonly occurring in the same litter. The snout is slender, the ears are large and thin and the eyes are prominent (Fig. 2). The tail is unicoloured and generally longer than the head and body length. The female has 10 mammaries; two pairs on the chest and three pairs in the groin, although an extra pair may occur on the chest on rare occasions.

Fig. 1. Norway rat.

The house mouse is a small slender animal with prominent eyes and ears (Fig. 3). It is quite variable in color and many different forms have been recognized. The ancestral stocks are generally the smallest forms and they have a tail considerably shorter than the head and body length. They live almost exclusively outdoors. Several forms have evolved living in close association with man and his dwellings. Commensal mice tend to be larger than the ancestral forms, the length of their tail being almost equal to that of the head and body. The belly color is dark grey, shading almost imperceptibly into the brownish-grey of the back. The female has 10 mammaries; three pairs on the chest and two pairs in the groin.

Fig. 2. Roof rat.

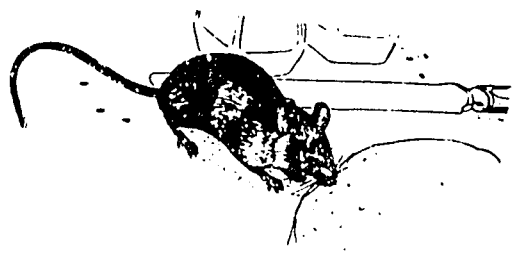


Fig. 3. House mouse.

D. Biology and Ecology

Rats and mice are primarily nocturnal animals and need special skills in order to move about and find food and shelter in the dark. They have a keen sense of smell, continually moving their heads and sniffing when active. They use the sense of smell to locate food, in identifying friendly or unfriendly mice or other animals and in finding mates. They have a well-developed sense of touch, primarily through the use of the long whiskers on the snout called the vibrissae. They use the whiskers to warn them of voids and objects in the darkness and use the body hairs in order to maintain contact with the walls and floor. Rats and mice can hear sounds in the ultrasonic range, much higher than that of man. They can make sounds in the ultrasonic ranges also, which helps them locate young mice that have strayed from the nest or keep track of each other in the dark. The rat and mouse eye is specialized for nocturnal vision; it has high light sensitivity but poor visual acuity. They can detect motion very easily under very low-light conditions. The sense of taste is much more acute than mans; mice and rats can detect bitter, sweet or acidic substances in their food or drinking water in extremely small amounts, measured in 1 or 2 parts per million (ppm). This ability to detect very minute strange tastes is what helps them in avoiding poisons when they first encounter them.

They have excellent physical abilities. The Norway rat is a prolific burrower, digging elaborate burrow systems in the soil. The roof rat and the house mouse have excellent climbing abilities, often living in the upper parts of houses and buildings. All can jump amazing distances for their size. Norway rats can jump vertically upward a distance of 70 cm and house mice can easily escape from a container 15 cm deep. They can drop a distance of 50 feet without harm. They are able to gnaw their way through wood, soft aluminium and soft brickwork and concrete. They have this ability because the incisor teeth grow continually and the outer layer wears away more slowly than the under layers, leaving a chisel-like cutting surface. All three commensal rodents are good swimmers and the rats can cross bodies of water like rivers and lakes.

They are mainly omnivorous, that is capable of eating a wide variety of foods. The Norway rat prefers cereal grains, meats, nuts, some vegetables, crustaceans and molluscs, roots and tubers and garbage. The roof rat feeds on nuts, seeds, fruits, field crops, sugarcane, coconuts, stored foods, insects and some meats. The house mouse will feed on most any stored food and causes field damage to maize, wheat, oats and other grains. It can live on the moisture content of the grain in storage facilities, having no need for a water source.

All three species are socially aggressive, being able to live in large colonies where the members known to each other get along tolerably well. However, adjacent colonies often will not tolerate members from other colonies, fighting with animals that wander over in their territory and running them off. They apparently recognize each other by a common odor which the stranger lacks.

They have a brief period before becoming sexually mature. In the house mouse it is 42 days, in the roof rat 68 days, and in the Norway rat is 75 days. The gestation period is short, 19 to 23 days and the young are weaned in 21 to 28 days. Litter size ranges from 6 in the house mouse to about 9 in the Norway rat and the number of young per year is in the order of 35 to 45 per female. These are considered high reproductive production figures and the commensal rodents are capable of rapid population growth when conditions are favorable.

Rats and mice live very short lives. The average life expectancy for house mice is in the range of 100 to 150 days (3 to 5 months), and for Norway rats and roof rats, most of the animals rarely live 8 months to a year before dying.

E. How do they affect man?

The commensal rats and mice have had a profound effect upon man. They brought the plague, called the Black Death, upon Europe in the 14th Century, killing between one quarter and one third of the then existing population before the disease ran its course. Besides plague, they spread murine typhus and rickettsialpox through their mites and fleas, leptospirosis through their urine and rat-bite fevers through their salivary secretions. They can contaminate our foodstuffs with bacteria that produce salmonellosis, a form of food-poisoning. They spread internal parasites, such as tapeworms, nematodes, cestodes, and protozoa, which can contaminate food and water.

They cause economic losses of stored foods throughout the world. Here in Pakistan, the common mouse in food storage facilities is the house mouse and it also occurs in farmers housing as an unwanted guest. The common rat in food storage facilities, grain markets and farmers houses is the roof rat. The Norway rat in Pakistan is restricted almost entirely to Karachi and a small population is reported to occur in the vicinity of the railway station at Lahore. The economic losses caused by commensal rodents in food storage facilities in Pakistan is fortunately low, but in many other parts of the world they are thought to destroy billions of dollars worth of stored foods.

Besides the losses of stored foods, are the damage to mans' structures, fiber and fabrics. The commensal rodents gnaw their way through barriers to obtain food and shelter, damaging doors, windows, walls and floors. They destroy storage bags, clothing, furniture, books, cartons, soap and

other commodities. They burrow into railway embankments, causing rails to sag, and ditches and dikes to wash out. They are known to start fires inside walls by gnawing on electrical wires and making short circuits. They damage expensive electrical equipment by gnawing the insulation off the wires, causing it to short out or burn up.

F. Ectoparasites of Commensal Rodents

The ectoparasites of commensal rodents are fleas, lice, mites and ticks. The most important ones are fleas and mites, since these transmit the organisms causing plague, murine typhus, scrub typhus and rickettsialpox.

The common fleas of rats and mice are given in the *Quick Guide to Common Fleas*, attached at the end of this article. The most important from a disease standpoint are the two species of *Xenopsylla*; *X. cheopis* and *X. astia*, both of which are capable of transmitting plague and murine typhus through their bites.

Several mites are of disease importance: the house mouse mite, *Allodermanyssus sanguineus*, which transmits rickettsialpox and several species of mites known as chiggers, *Leptotrombidium* species, which transmit scrub typhus.

G. Ectoparasite Control

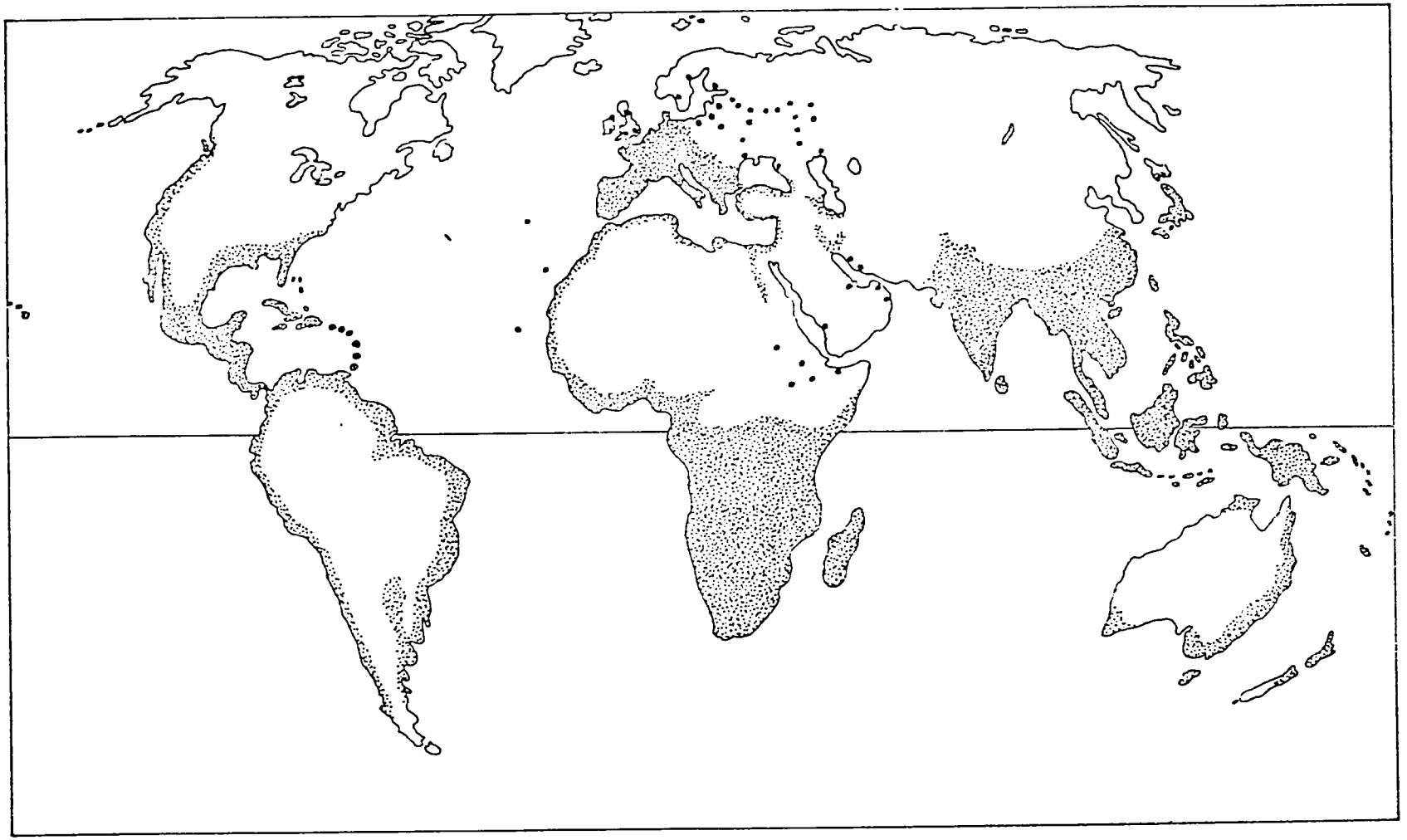
Control of ectoparasites (fleas, lice, mites and ticks) is essential to prevent transfer of rodent diseases to man. Ectoparasites feed on the blood of their rodent hosts and can thereby become infected. When the hosts are killed by trapping or poisoning, their ectoparasites sometimes, by chance, select a person as temporary host. If the ectoparasites are infected, they may transfer the disease-causing organisms to that person. When disease is thought to be present in a rodent population, ectoparasites should be killed before or concurrent with rodent control measures. To carry out ectoparasite control:

1. Inspect the area for signs of rat or mouse activity, especially for rubmarks at the base of walls and for evidence of pathways and burrow openings.

2. Select an appropriate insecticide for ectoparasite control. Since it is mainly fleas that are to be controlled, use either 5% carbaryl, 5% malathion, 1% propoxur, 2% fenitrothion or 2% pirimiphos methyl.

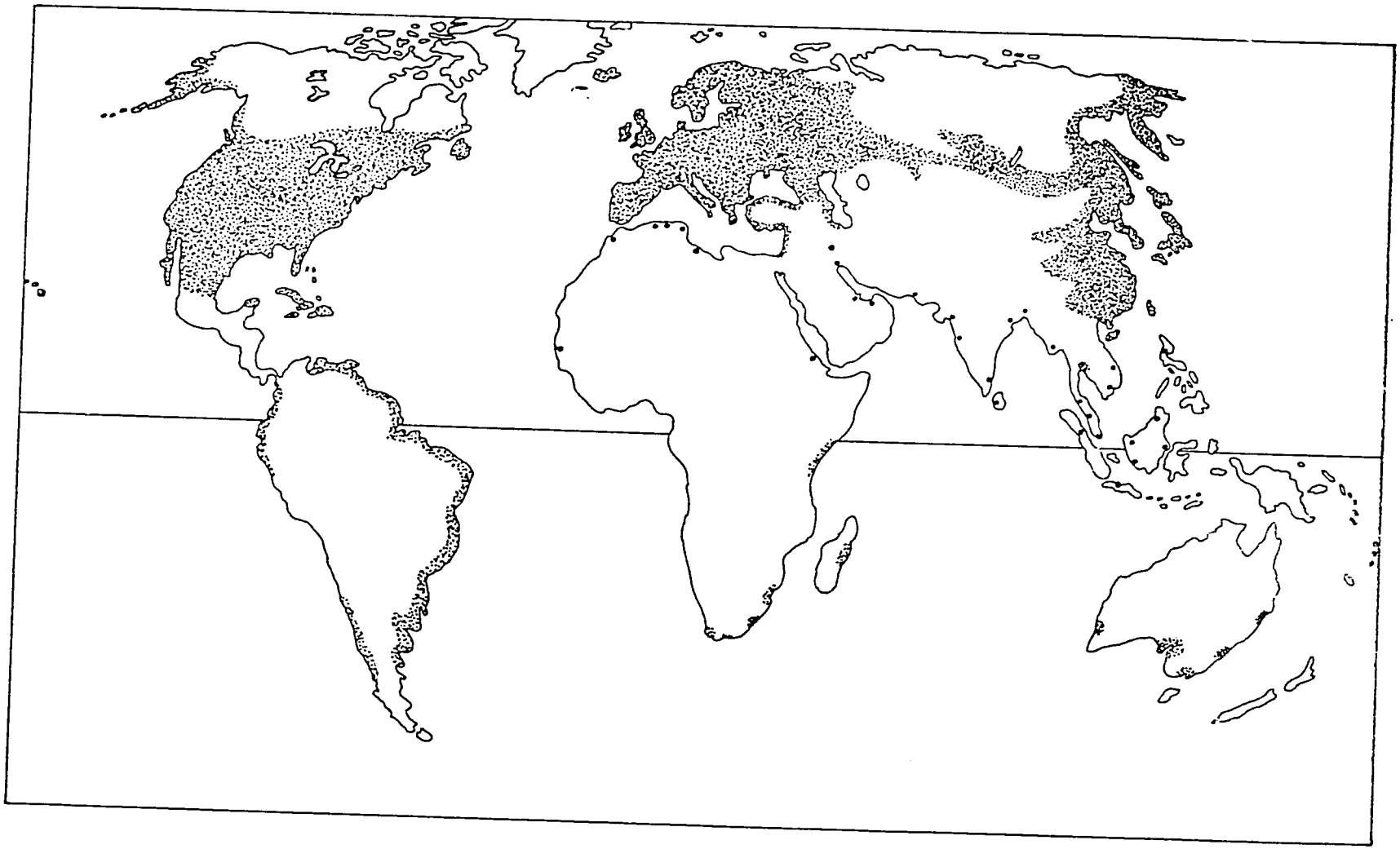
3. Treat all runways and burrow openings with one of the insecticidal dusts mentioned above. Dust the vertical surfaces against which rodents may brush, using a dust gun or hand shaker. When anticoagulant baits are laid in bait stations, apply insecticidal dusts at the openings to the stations.

4. Rats that come into contact with the insecticide dust carry it on their feet and fur into their burrows and nests. Fleas are normally killed within 48 hours following dusting.



Appendix 1. Distribution of *Rattus rattus*.

Appendix 2. Distribution of *Rattus norvegicus*.

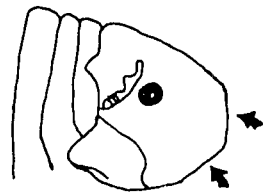


APPENDIX-3: FIELD CHARACTERS AND MEASUREMENT OF COMMENSAL RODENTS

Character	Norway rat	Roof rat	House mouse
Weight	150-600 gm	80-300 gm	10-21 gm
Head and body	nose blunt, heavy, stocky body, 18-25 cm	nose pointed, slender body, 16-21 cm	nose pointed, slender body, 6-10 cm
Tail	shorter than head plus body, darker above and lighter below, with short, stiff hairs, 16-21 cm	longer than head plus body, uniformly dark coloured, naked, 16-25 cm	equal to or little longer than head plus body, uniformly dark coloured, naked, 7-11 cm
Ears	relatively small, close-set, appeared half buried in fur, rarely over 20-23 mm	large, prominent, thin and hairless, stand well out from fur, 25-28 mm	prominent, large for size of animal, 15 mm or less
Fur	brownish-grey on back, greyish on belly	brownish-grey to blackish on back, belly may be white, grey or greyish-black	one subspecies brownish-grey on back, greyish on belly, another greyish on back and greyish-white on belly
Habits	burrows, swims and dives easily, gnaws, lives indoors and outdoors, in sewers and drains	agile climber, gnaws, often lives off the ground in trees, shrubs, etc., lives indoors and outdoors	climbs, sometimes burrows, gnaws, lives indoors and outdoors

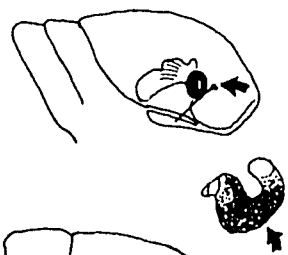
A QUICK GUIDE TO COMMON FLEAS

Pronotal and genal combs absent
Front margin of head with two angles



ECHIDNOPHAGA
gallinacea

Front margin of head rounded, ocular bristle in Spermatheca in female partially pigmented

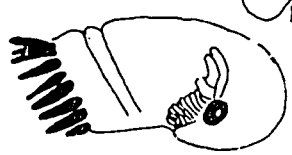


XENOPSYLLA
cheopis
astia
brasiliensis
vexabilis

Front margin of head rounded, ocular bristle below eye, Spermatheca in female unpigmented

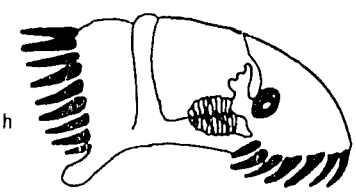
PULEX
irritans

Pronotal combs only



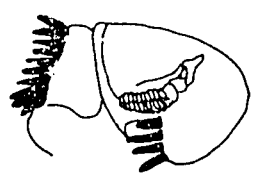
NOSOPSYLLUS
fasciatus

Pronotal and genal comb present
Genal comb with more than 5 teeth



CTENOCEPHALIDES
felis
canis

Genal comb with only 4 teeth, eye absent



LEPTOPSYLLA
segnis

PORCUPINE: BIOLOGY, DISTRIBUTION AND BEHAVIOUR

By Ejaz Ahmad

A. Biology and Behaviour

The crested porcupine is the largest rodent found in the Indo-Pak subcontinent. Normally they weigh from 15-18 kg but they can attain weight up to 27 kg. The popular name is derived from the long wiry hairs on the neck which can be erected to form a crest. Porcupines have powerful limbs with four digits on the forefeet and a vestigial thumb. There are five digits in the hind feet and the sole is naked. Each digit terminates in a very powerful long claw which assist them in digging. The head terminates in a broad blunt muzzle. Ears and eyes are relatively small. The lower part of the body is thinly covered with dark brown and black bristle-like hair. The incisors are extremely broad and powerful, being coated with pale yellow enamel.

From the fore part of the crown to behind the shoulders the hairs on top of the body are modified into very long slender spines generally of an all black colour and measuring up to 35 cm (Fig. 1). These spines can be erected in the form of a prominent crest when the animal is excited or angry. From the mid-dorsal region and down the lower flanks the hair is further modified into the well known porcupine quills. These are characteristically banded alternately with black and white. The tail is quite short, rarely more than 1/5th of head and body length and clothed with modified quills which are generally all white in color, very short and broad, being attached to the body by needle like points. These short quills are open-ended and when the animal wishes to warn of an enemy it produces a rattling or rustling noise by quivering its tail quills. The female has six mammae and these are situated along the lower flanks instead of under the belly as is the case with all other rodents. This makes it possible for the baby porcupines to suckle whilst the mother is standing, lying on her belly or sitting.

Fig. 1. Crested porcupine.

Porcupines are strictly nocturnal in habit. In fact they seem to be very cautious and shy rodents, emerging from their burrows only well after dark. Porcupines generally dig their own burrows and these can be very extensive (sometimes upto 18 m) with side entrances and descending to considerable depths underground. Often two or three individuals appear to share the same burrow system and will occupy such a burrow for several years if not disturbed. They appear to be partly social in living habits.

Porcupines are herbivorous, but prefer the bark of certain tree species and also certain roots, bulbs and succulent tubers. They also feed on ripe fruit. They are very destructive of agricultural crops and do extensive damage to maize, groundnut and occasionally to sugarcane in the Punjab. They also like potatoes and sweet potatoes as the tubers are maturing. In Baluchistan they are notorious for stealing ripe water melon. Food is located by hearing it fall (they have excellent hearing), smelling it or via long vibrissae.

Porcupines will wander over considerable distances in their nightly foraging and can travel as far as 16 km to feeding areas. It has been reported that porcupines carry bones to their burrows and have the habit of gnawing these. Perhaps they obtain minerals necessary for quill development.

Evidence of their presence in certain areas is presence of their burrow openings (Fig. 2), their foot prints, their quills and sometime their feces. Porcupines produce very characteristically shaped elongated feces, often in clusters and these readily betray their presence.

Females often excavate a separate burrow in which they produce their young. The gestation period is comparatively prolonged at about 112 days. Generally 2 to 4 young are born and they are well developed at birth and have their eyes open. Young leave the nest after a week when quills have hardened. The spines are comparatively short and quite soft for the first few days. Males may share the same burrow when the young are born. In some regions litters generally seem to be produced in February and March. Young are comparatively slow-growing and remain for several months with the mother. The young are weaned at 16 weeks.

Fig. 2. Porcupine burrow.

Porcupines are well protected against predators, yet they appear to be a favoured food amongst many of the larger carnivores. They are provided with an audible warning device on tail. When threatened with danger the porcupine will often erect its quills and rattle them together as well as making grunting noises. If the attacker does not heed these warnings, it then often runs rapidly backwards or side ways into the aggressor. Its quills are immediately shed if they become impaled on any object. The old belief that a porcupine can actually shoot out its quills at an aggressor is without foundation.

In the wild, they can survive for more than eight to twelve years.

B. Distribution/Ecology

In Pakistan they are found in most parts of the country (Fig. 3). They occur in steppe mountain regions of upto 2900 m elevation. They are found in sandhill desert areas, as well as in the Himalayas. They are common in Las Bela in the Kirthar Range, throughout the valleys of Baluchistan and into the outer hills of the Himalayas. They are found commonly in the Salt Range, throughout the Murree hills, Hazara district, and even upto 2770 m elevation in the forest above Shogran. They are also found in the main valley of lower Chitral as well as in the Vale of Swat. They occur around Bannu and in the Kurram valley.

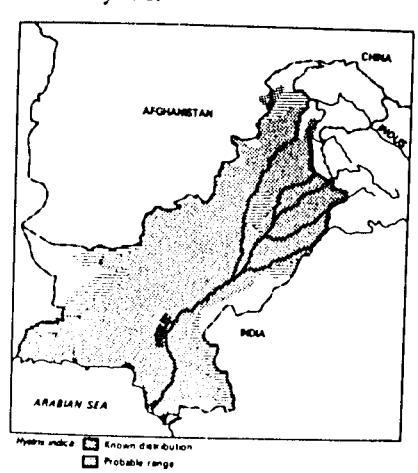


Fig. 3. Distribution map.

The crested porcupine seems well able to hold its own even with the increase in human population and gradual destruction of wilderness areas. Cultivation of crops such as sugarcane, maize, etc., and the creation of irrigated forest plantations may even have fostered its spread and increase in the Punjab. It is common in Baluchistan and causes serious damage to orchard fruit trees, gnawing off the bark and even cutting right through the tree bole.

C. Damage Pattern

1. Groundnut

Porcupines damage and kill the plants by clawing out the groundnuts from under the roots. The damage extends into the soil about 2.5 to 7.0 cm. The clawed area generally resembles loose soil under the plant. Intact, partially consumed and empty groundnut shells are scattered about the clawed area. The attack usually is on a series of plants in a restricted area such as a corner of a field and as many as 30 to 40 plants may be damaged in one night.

2. Maize

Porcupines cannot reach the maize cobs because of their small size, so first they cut the stem from the base and when the plant is in reach of the animals, they will eat the cobs. Porcupine damage to maize is not restricted to corners of field, it can be found any where in the field.

3. Forestry Seedlings

Porcupines damage forest trees. They cut the plants at early stages when they are planted and also debark the older trees. They prefer some trees and do not damage others even in the same enclosure. Their preference varies from place to place. In Azad Jammu & Kashmir it is noted that porcupine damaged all the seedlings of Chir pine and *Robinia*, and did some damage to plants of wild apricot, poplar and walnut, but no damage was observed to the plants of *Alianthus*, *Eucalyptus* and *Ipil ipil* plants. In Lehri Nature Park near Jhelum, porcupine damage was noted to *Ipil ipil* and *Parkinsonia* plants. The plants were cut 6 inches above ground. In irrigated forest plantations of Punjab *Malia azedarach* is the most preferred tree followed by *Morus alba* and *Dalbergia sissoo.*

CONTROL OF PORCUPINE AND MURREE VOLE IN CROPS, ORCHARDS AND FORESTS

By Abdul Aziz Khan

A. Control of Porcupine

Introduction

The crested porcupine (*Hystrix indica*) is the largest rodent found in Pakistan although it looks very different from a rat or mouse in appearance. The adults weigh upto 18 kilograms. They are nocturnal and omnivorous and inflict heavy damage to potatoes and root crops, maize, sugarcane, fruit trees (citrus, mango & peach), forest nurseries and plantations, particularly mulberry, shisham, bukain and simbal. They also cause breaches in link canals and minor irrigation channels. Recently, in the Hazara division and Azad Kashmir, porcupines have become a limiting factor in the reforestation programme of the forest departments.

The areas where they are most abundant and troublesome are adjacent to foothill regions, such as Dadu and Larkana in Sind; Quetta and Ziarat in Baluchistan; Jhelum and Mianwali districts in the Salt Range of Punjab and both Mardan and Peshawar districts of NWFP. Their other favourite habitats are the irrigated forest plantations of Punjab and Sind and along the embankments of link canals of Indus basin system and old barrages of Punjab and Sind.

Before taking up any operational control measures against porcupines, particularly in irrigated forest areas, it is highly desirable that surveys be carried out to map out exact locations of porcupine dens. This will help in planning and selecting the correct type of materials and methods and in the evaluation and monitoring of the whole programme.

Control Methods

1. Fumigation

One of the ways of controlling porcupines is to locate an occupied den and fumigate this to kill the occupants. An occupied or active den can easily be recognized by the characteristic foot tracks, elongated fecal pellets and the dropped quills. Generally, fumigation can be done with cyanogas, cymag, phostoxin or detia. There may be two or more entrances to the den. So, it is advisable to select one active entrance and close the other entrances with dirt and vegetation. Fumigation is easily carried out in daytime when the porcupines are known to be inside their dens. For cyanogas and cymag fumigants, the foot pump is commonly used for this purpose with a 1.5 meter long and 1.3 cm diameter rubber hose pipe. Insert the hose deep into the tunnel, then around the hose place a sufficient quantity of brushwood and then dirt to close the entrance. Apply 10-20 strokes on the pump and then carefully pull back the hose. Put some more dirt on the already sealed entrance so as to avoid any leakage of gas. Check fumigated dens after 24 hours and if they have not been reopened, one can assume a successful kill. Refumigate all burrows that are reopened.

If a foot pump is not available, Phostoxin or Detia tablets can be used. Insert 10-15 tablets in the active den with the help of a long-handled shovel. Then pack the entrance with brushwood or vegetation and seal it firmly with dirt. A new burrow or one in hard stony soil may require only 5-10 tablets while the old and deep burrows need 15 tablets for effective fumigation.

A two-ingredient pyrotechnic device has been successfully evaluated in Pakistan. This device is simply a gas cartridge containing 65% by weight of sodium nitrate and 35% ground charcoal. Devices weighing 200-250 grams of ingredients gave 80-95% reduction of porcupines in field trials. After igniting, the device is placed deep into the burrow. The burrow is sealed with brushwood and dirt. As a result of the burning of ingredients, carbon monoxide is produced which kills the porcupines in the dens.

2. Baiting

Baiting with strychnine and sodium monofluoroacetate (1080) using potatoes and apples as bait results in a quick kill. A very small quantity of these poisons at the end of a thin stick is smeared on cut potatoes and apples and then placed deep into the burrow in the evening. The operator must wear rubber gloves when using these poisons. Also, the stick, after baiting, should be burnt or left deep in the burrow. The following morning baited burrows should be inspected. Fresh foot tracks will not be observed 24 to 48 hours after baiting if the bait was eaten. Baiting with strychnine and 1080 has proved very effective along link canals in Punjab and in "Karezes" in Baluchistan. These poisons should be used only by experienced and qualified professional persons, such as a Plant Protection Officer or Range Forest Officer. Permanent bait stations with strychnine treated (5.65%) salt blocks have been used effectively in forest areas. Porcupines have a liking for salt taste.

Recently, anticoagulant rodenticides have been used to control porcupines with considerable success. Trials in Azad Jammu and Kashmir, using coumatetralyl as the rodenticide, were entirely successful. Baits were made of wheat flour made into a dough, using molasses as an attractant, and the coumatetralyl at 0.0375% concentration. These were made into 80 to 100 g dough balls and 2 to 3 balls were placed into each active den through the burrow openings. Baiting was done daily for 5 to 7 days. Brodifacoum baits (0.005% concentration) were used the same way near Fateh Jhang, but dens were baited only for 3 days.

3. Flooding the Burrows

Flooding the burrows used to be practiced only in irrigated forest plantations where such facilities can be made available. This usually consists in diverting the irrigation water from the small water channels into the burrows. The porcupines are thus flushed out and then killed manually. For this purpose, it takes at least 10-30 minutes before the den is completely filled. Also, this operation requires a large quantity of water which is usually needed somewhere else. Generally, when the den is flooded, it collapses with a heavy rush of water into it. Since most of the burrows are located in uncommanded areas, the application of this method is difficult and impracticable. In such cases fumigation and baiting should be done.

4. Trapping

Trapping by forest departments has been practiced by means of "Duplex traps" and the VPCL has used cage traps. Baits used were vegetables, sweet potato and meat. Experience has shown that trapping is the least effective measure in controlling porcupines. The capital cost of the traps and their management, added to their transportation, are some of the limiting factors in using them on large scale. Keeping this in view it can be concluded that this method is not recommended.

5. Hunting and Shooting

Expert hunters (shikaris) are attracted when reasonable bounty rates are offered. Present rates are very low and this method will not prove successful unless bounties are increased.

6. Use of Repellents on Nurseries

The use of some chemical repellents is one effective means to protect the forest nurseries from porcupine damage. Forest departments have achieved high success in preventing damage by spraying endrin, although this method would not now be recommended. Other possibilities could be the use of some kinds of fungicides such as "Thiram" and bone tar oil. These repel the animals on the basis of taste and/or odour, making the treated plants less preferred. Effectiveness of repellents therefore often depends on the availability of other natural food for porcupines and the degree of their hunger.

B. Control of Murree Vole

Introduction

The Murree vole, *Hyperacrius wynnei*, belongs to the family Microtinae of which many species and forms are distributed throughout the cooler regions of the northern hemisphere. This is a small burrowing rodent adapted to live in the pine forest zone at high elevations in the Punjab and NWFP. It is a serious pest of apple trees, maize and potato crops. It gnaws the bark of apple trees below ground level and in winter forages upon the vegetation and grasses. With complete debarking, the trees are killed or, when partially debarked, fruit production decreases.

Control Methods

Various control measures can be adopted successfully to prevent the losses caused by voles. These are described here based on the experience of the Vertebrate Pest Control Laboratory and knowledge gained in European countries. Basically, the fundamentals of integrated pest management (IMP) are put into practice in these vertebrate pest problems.

1. Baiting

In the case of voles, baiting with acute or anticoagulant rodenticides is conducted starting by the end of December and can be continued until the end of February or middle of March if sufficient snow cover is still there. The voles during these months are highly active, making tunnels in the snow and feeding on the surface vegetation. If baits are broadcast or laid in bands or placed in the tunnels, the vole population can fairly well be controlled. The best bait material is oat-meal used as it is marketed as a breakfast cereal. Oat-meal is mixed with 1% zinc phosphide and a limited quantity (1-2%) of vegetable oil as a sticker. Pelleted baits (0.005%) of second generation rodenticides, i.e. brodifacoum, can give a high reduction in vole populations and protection to orchards, crops, etc.

2. Protective Repellent Coatings

Rodents do not like to get their fur sticky or to gnaw on highly viscous material. Removing the top 6 inches of soil around the base of apple trees and painting the exposed portion with a band of "OSTICO" brand (ICI Product) or a specially prepared sticky paste developed by Vertebrate Pest Control Laboratory, are highly effective as repellents. The basic ingredients of this paste are rosin, paraffin wax and castor oil. For details contact the Vertebrate Pest Control Laboratory, in Karachi. Voles come into contact with these non-toxic compounds when burrowing underground and are repelled. After pasting the tree trunk portion, the dirt is put back, and leveled as before treatment.

3. Protective Stone Collars

Voles can burrow through gravel soil but will avoid very closely packed stones and this method of putting a physical barrier will stop damage to trees. The method involves the removal of dirt around the tree trunk to a depth of 9 inches without damaging the root system. The cavity thus excavated

should extend all around the tree to a radius of 18 inches. This cavity is then filled in with crushed stones and carefully packed around large exposed roots. Voles will not attempt to burrow through such stones. This protective layer will last for the life of the tree.

4. Other Possible Control Measures

In general, fungicides have some repellent action to rodents and rabbits. Of these, Thiram, trade named "ARASAN", is the most effective, and is used elsewhere in the world as a rabbit repellent by painting it on tree trunks but this product has not been evaluated in Pakistan against voles.

Spray of insecticides like endrin or dieldrin on vegetation will drastically reduce the vole population but these insecticides tend to persist in the soil and are not recommended. Reducing ground cover can be another alternate in the management of vole populations. Herbicides, such as atrazine or 2, 4-D can be used to reduce early vegetation growth. Low vegetation can also be reduced by disking or other mechanical means or even by burning. Providing alternate foods to voles in the winter months may be one method to prevent tree damage and should not be overlooked. The role of "catch" crops has yet to be explored in sufficient depth to make it an acceptable method.

VERTEBRATE PEST - BORNE DISEASES

By Rafia Rehana Ghazi

A. Rodent Borne Diseases

The economic aspects of rodent infestations have in many instances over-shadowed their public health significance. Rodent pests that destroy field crops and stored food are also of considerable importance in public health. Traditional and newly emerging rodent-borne diseases shall continue to threaten man who is changing the environment aiming at a better life. Rats eat about 10% of their weight in food each day and contaminate a great deal more with their droppings and urine, thereby rendering it unfit for human consumption.

A few diseases transmitted by rodents are:

1. Leptospirosis

This is a disease of domestic rodents. The actual disease organism is a spirochaete. Rodents such as the house mice, *Mus musculus*; the roof rat, *Rattus rattus*; and the Norway rat, *R. norvegicus*; are known to be capable of transmitting the disease. Rodents transmit the disease organism through their urine. The disease is also known as Weils disease or infectious jaundice. Humans get infection by handling infected rodents or contacting moist soil on which rodents have urinated. Further it is important to note that cattle, swine and dogs are also able to transmit this disease (in the same way).

Serological diagnosis of the disease was carried out at the Vertebrate Pest Control Laboratory. Representative rodents with positive sera were:

a) *Tatera indica*
b) *Meriones hurrianae*
c) *Rattus rattus*
d) *R. norvegicus*
e) *Nesokia indica*

In addition serum samples of sheep, goat and buffaloes were also found positive for the leptospirosis disease in Pakistan.

2. Salmonellosis

This disease is due to food-poisoning by *Salmonella* bacteria of which more than 30 species are known to survive in humans. *Salmonella typhimurium* and *S. enteritidis* are the two salmonella bacteria associated with rodents. *Rattus rattus, R. norvegicus* and *M. musculus* are known to be capable of transmitting the disease. In addition serological diagnosis for salmonellosis gave positive results for the following rodents sera:

a) *Meriones hurrianae*
b) *Tatera indica*
c) *Rattus rattus*

Buffalo, cow, sheep and goat's sera were also tested, which gave positive results for the disease.

The bacteria are transmissible to humans by the rodent feces, unrefrigerated food, improperly cooked meat of an infected animal, and unsanitary conditions.

3. **Lymphocytic choriomeningitis**

This is a viral disease. It is associated primarily with house mice. The virus is transmitted by the mice usually through its nasal secretions, urine, and feces. The disease begins with an influenza-like attack and after two days meningeal symptoms suddenly appear.

4. **Tick borne encephalitis**

This is a viral disease. Serological diagnosis were positive for *R. rattus* serum. Buffalo, sheep and goat's sera were also positive for the disease. This disease is transmitted by the bite of an infected tick or by consumption of raw milk from infected cattle. The fever is associated with the central nervous system. In addition, human sera were also reactive with tick-borne encephalitis antigen.

5. **Q fever**

This is an acute disease of rickettsial origin, the rickettsia being *Coxiella burnetii*. Natural infection has been demonstrated in at least 40 species of ticks. In Australia, Africa and North America the organism has been isolated from wild mammalian hosts of infected ticks.

Man usually contracts Q fever by inhaling dust particles contaminated with rickettsiae originating from livestock and by the excreta of other mammals. Complement fixing antibodies against *Coxiella burnetii* were detected in Pakistan in 3 of 65 rodent sera, representing 6 species. It is also important to note that positive serologic reactions were obtained in 5 out of 18 tested human sera. Four of the 5 human sera were found in persons between 20 - 30 years of age.

Q fever organisms appear to be prevalent in Karachi and Sind, infecting commensal rodents, domestic animals, and man. Inhalation of dust, contaminated by the excreta of infected animals, can also lead to infection of humans and livestocks.

6. **West Nile fever**

This is an acute, mild, febrile disease. Occurs in South West Asia, Middle-East and tropical and subtropical Africa.

The virus is introduced through the bite of a *Culex* mosquito which produces a generalized systemic infection characterized by lymphadenopathy and some times accompanied by a maculopapular rash. The virus may produce fatal encephalitis in older people who have low or delayed antibody response.

Ticks may play a role as reservoir vectors. Nymphs of the ticks acquire infection by engorging on viremic mice. The virus multiplies inside the nymphs body and persists into the adult stage. The ticks, in turn, can pass the virus to the mice.

7. **Scrub typhus (Chigger-borne Rickettsiosis)**

This is an acute, febrile, typhus-like disease transmitted by larval trombiculid mites (Chiggers) which parasitize the rats. The disease has a wide distribution in eastern and southern Asia and the Pacific. Rats of the genus *Rattus* serve as prime hosts of the Chigger *Leptotrombidium*. Other mammals and shrews are known to serve as secondary hosts.

Rickettsia tsutsugamushi (*R. orientalis*) is a small obligate intracellular bacterial parasite, which grows free within the host cell cytoplasm. Man acquires the disease by the bite of an infected Chigger, when he intrudes into an endemic foci. In temperate zones most vector chiggers are active during the warm months and hence the disease is seasonal. It is more prevalent in the tropical and subtropical regions.

Khan and Gilani in 1961 reported an outbreak of Scrub typhus infection in the Border Police and the Army troops in Sialkot. This was the first report of the disease in Pakistan. The vector reported was *Trombicula deliense*. Later Traub and Wisseman in 1967 reported the occurrence of the disease at some unusual habitats in Pakistan. The authors discussed the presence of Scrub typhus infection in rodents or trombiculid mites at (1) Alpine terrain at 10,500 ft. elevation in the Kaghan Valley of the Himalayas, where the snow remains on the ground for 9 or 10 months of the year; (2) in the mountain deserts of Gilgit Agency; (3) in the semi-deserts of Multan; and (4) in the plains of Lahore district. In these areas *Leptotrombidium deliense* is known to be abundant.

Natural infection with *R. tsutsugamushi* was demonstrated in almost all habitats, virtually all from tissues of rodents. The highest rate of positive isolations was from the temperate coniferous forest zones of the Kaghan Valley (29 out of 119, or 24%) primarily from the indigenous mice such as *Apodemus, Alticola* and *Hyperacrius*.

The scrub typhus rickettsiae were isolated and documented for the first time from the following mammalian hosts:

a) *Alticola roylei* (Vole)
b) *Hyperacrius fertilis* (Burrowing vole)
c) *H. wynnei* (Burrowing vole)
d) *Millardia meltada* (rat)
e) *Nesokia indica* (Burrowing rat)
f) *Tatera indica* (Gerbil)

8. <u>Leishmaniases</u>

The leishmaniases comprise a group of several different diseases which are widely distributed in tropical and subtropical areas, ranging in severity from skin lesions to severely mutilating mucocutaneous involvement or visceral infections which are always almost fatal if not treated.

Kala-azar: Caused by *Leishmania donovani* (or visceral Leishmaniasis); if untreated, this is a highly fatal disease. It is transmitted by sand-flies of the genus *Phelobotomus*. Rodents are regarded as important reservoirs. The disease is found in most tropical and subtropical areas of the world. A recent major epidemic has occurred in north east India.

Cutaneous leishmaniasis (Oriental sore): Caused by *L. tropica*: It is found in Soviet Asia, Middle East, and the Mediterranean, including North Africa. Cases have also been observed in Uthal, Baluchistan and Karachi, in the Sind province. Several of the gerbillinae are the proven reservoirs of the disease. Incidence in some countries of the Middle East is 100%.

Cutaneous leishmaniasis (Chiclero ulcer) of the New World, (*L. braziliensis*). This form may give rise to a much more serious disease. It has been reported from a number of cricetine rodents which appear to serve as reservoirs.

Until recently the extent and severity of this group of diseases as a major public health problem was largely unrecognized. The Leishmaniasis Steering Committee has recently estimated that there are 400,000 new cases each year, but the number of people with chronic and long-standing incurable forms of the disease is unknown.

Human Leishmaniases are known to be caused by at least 13-15 different species and subspecies of parasite of the genus *Leishmania*. These parasites are transmitted to man from other infected persons or mammals by sandflies when taking a blood meal. Leishmaniases have been reported from about 80 countries.

9. Plague

Plague is primarily an infection of wild rodents caused by the bacillus *Yersinia pestis*. Fleas subsisting on wild rodents and frequenting their nests and burrows become "blocked" by the bacilli accumulating into a plug which blocks the proventriculus. Part of this plug is regurgitated by the flea when its again attempts to feed, thereby infecting the bitten rodent. Effective vector species are those in which blood-meals frequently cause blockage, e.g. *X. conformis, X. cheopis, X. skrjabini, Oropsylla silantiewi* and *Pulex irritans*, whereas *Ctenophthalmus* spp. very seldom become blocked. Likewise, strains of plague bacilli characterized by a more viscous cell wall are more virulent because they cause a higher proportion of fleas to become blocked.

Plague epidemics among animals (epizootics) were first recorded in the 1950's among the marmots of Mongólia. Sylvatic, rural or wild-rodent plague was subsequently discovered among sciurid, cricetid, murid and dipodid rodents in many parts of the world, constituting reservoir foci of *Y. pestis*.

Meanwhile, human plague, involving domestic (or commensal) rats and mice, originated in interior China in the mid-19th century, and reached Canton and Hong Kong in 1894. It quickly infected the major sea-ports of the world by passage in ships infested with rats and the oriental rat flea, *X. cheopis*, having already reached Calcutta and Bombay by 1898. Urban plague in cities and towns came to be transmitted not only by the rodent fleas *X. cheopis, X. astia* and *X. brasiliensis* as well as *Nosopsyllus fasciatus*, but also by other cosmopolitan commensal fleas such as *Pulex* and *Ctenocephalides*. The number of flea species known to be implicated in plague transmission totals more than 200.

10. Rat-bite fever

Rat-bite (or Sodoku) is, as its name suggests, is transmitted to man by the bite of infected rats, the bacteria causing rat-bite fever being found in the teeth and gums of rats. The latter show no symptoms of the disease but in man the symptoms are a relapsing fever and muscular cramp. The fever is caused by a spirochaete, *Spirillum minus*, present in the salivary glands of infected rats.

11. Murine typhus

Murine typhus is caused by *Rickettsia mooseri*. Murine typhus, also called flea-borne typhus, is an infection of commensal rodents in the subgenus *Rattus*, although *R. mooseri* is occasionally found in *Mus, Suncus* and even cats and opossums. Fleas and sometimes lice are associated with murine typhus transmission, which is essentially of the contaminative type, even possibly by the aerosol route. Human infection results from contamination from the dried feces and crushed bodies of the fleas. The great majority of murine typhus outbreaks have been associated with the presence of *X. cheopis*.

12. Tularemia

The infection of man by the bacillus *Francisella tularensis*, present in lagomorphs and rodents, was first found in California in 1911. Tularemia was found to be transmitted primarily by the deerfly *Chrysops discalis*. Ticks and fleas are also involved in transmission.

13. Parasitic worm infections

a) Dog heartworm

This disease is due to infection by microfilariae of nematode worms. In some cases the heartworm is *Dipetalonema reconditum*, is transmitted by fleas.

b) Tapeworms

Fleas act as intermediate hosts for three kind of cestode infections, which can accidentally infect children, namely the dog tapeworm and two species of rat tapeworms. The most important is the dog tapeworm, *Dipylidium caninum*, a parasite of dogs and cats. The tapeworm eggs passed in their feces are ingested by flea larvae, usually *Ctenocephalides* or *Pulex*. By the time the flea has reached the adult stage, the tapeworm eggs have developed into cysticercoids, which grow into tapeworms when such infected fleas are eaten by the dog or cat during grooming. Actually a score of *Dipylidium* species are known, and it is probable that several of those are also flea- transmitted.

The two rat tapeworms, *Hymenolepis diminuta* and *H. nana*, have a similar life-cycle. Eggs ingested by larvae of the rat fleas *Nosopsyllus fasciatus* and *X. cheopis*, or by *Ctenocephalides* and *Pulex*, develop to the cysticercoid stage in the fleas, which are then ingested by commensal rats and mice and develop into tapeworms. Other insects may serve as alternate hosts for *Hymenolepis* spp., and domestic beetles such as *Tribolium* have proved to be more effective than rat fleas as alternate hosts for *H. diminuta* in Egypt. Nevertheless, three other *Hymenolepis*, namely *H. murina, H. microstoma* and *H. citelli*, have been found in flea larvae. Cats infected with *Ctenocephalides felis* fleas in Jordan carried the tapeworms *Taenia taeniaeformis* and *Echinococcus multiocularis* as well as *H. diminuta*.

B. Bird Borne Diseases

Most of the birds have potential for transmission of diseases to humans and domestic animals as have been evidenced by numerous laboratory tests and documentations. Specially the pigeons, starlings and English sparrows are known to be capable of transmitting certain microbial and parasitic disease. They carry the disease agents, create health hazards, produce pollution and above all they cause staggering economic losses by damaging agricultural crops. It would be interesting to quote that hungry birds can literally wipe out a farmers crop if allowed to feed for a few days or a few weeks. On the other hand most of the 8,000 bird species are very beneficial and a great pleasure to observe.

One of our foremost desires is good health. Protection from disease is also important to domestic animals and poultry. Pest birds often create conditions for growth of organisms that cause disease. Dermatitis (skin-infection) caused by the ectoparasitism may result in a great variety of diseases. A review of literature reveals more than sixty transmissible diseases associated with most of the pest birds.

1. Bacterial Diseases

Erysipeloid, fowl cholera (Pasteurellosis), fowl typhoid, infectious coryza, listeriosis, paratyphoid, pasteurellosis, pullorum disease, salmonellosis, spirochaetosis, tuberculosis, ulcerative enteritis, vibriosis and yersiniosis can be transmitted by birds.

2. Mycotic Diseases

Aspergillosis, blastomycosis, candidiasis, cryptococcosis, histoplasmosis and sarcosporidiosis.

3. **Protozoal Diseases**

American trypanosomiasis, coccidiosis, haemoproteus, leucocytozoonosis, toxoplasmosis and trochomoniasis.

4. **Rickettsial and Chlamydial Diseases**

Chlamydiosis, prioplasmosis and Q fever.

5. **Viral Diseases**

Encephalitis, eastern equine encephalitis, venezuelan encephalitis, west Nile encephalitis, meningitis, new castle disease, pox and transmissible gastroenteritis.

6. **Parasitic cestodes**

Davania proglottina, Raillietina tetragona and Taeniasis.

7. **Parasitic Nematodes**

Capillariasis (3 spp.), aispharynxiasis, eye worm, tape worm and tetramariasis (2 spp.).

8. **Parasitic Trematodes**

Schistosomiasis. *Brachylaemus commutatus, B. fuscatus, Collyriculum faba, Cotylurus conutus, Cryptocotyle convacum, Echinoparyphium paraulum, E. recurvatum, Echinostoma revolutum, Haplorchis pumilio, Hypoderaeum conoideum, Plagiorchis muris, Postharmostomum gallinium, Riberiola ondatrae, Tamerlania bragai*, Dermatosis and Acariasis.

Some of the above listed diseases are briefly described here:

a) **Erysipeloid**

This is a skin disease. It affects humans, cattle, horses, sheep, goats, chickens, turkeys, ducks, dogs, cats and swines. The disease usually appears as an eruption of skin, being slightly swollen. It generally starts as a wound in the skin and is accompanied with a sensation of burning, throbbing pain, and intense itching. The infection starts on the face but it may be on any part of the body. There may be headaches, chills, pain in joints, fever and vomiting. The disease is sometimes fatal to young children.

b) **Fowl Typhoid**

This disease is caused by *Salmonella gallinarum*. Symptoms include loss of appetite, increased thirst, weakness, drowsiness, yellowish-orange diarrhoea and anemia.

c) **Coryza**

This disease affects chickens. It is caused by a bacterium, *Haemopilus gallinarum*. Symptoms include sneezing, wheezing, cough accompanied by mucous discharge from the nose, and abnormal breathing due to respiratory tract infection.

d) **Listerioses**

It is caused by the bacteria, *Listeria monocytogenes*. This disease causes changes in the nerve cells and nervous system. It can also cause meningitis in newborns and still-birth. Transmission occurs by air-borne infected dusts and by contamination of feed. Cattle may become nervous and walk in circles. The disease has been isolated from pigeons. It may also be transmitted by oral or fecal route.

e) **Paratyphoid**

The disease is caused by many types of *Salmonella* sp. It affects humans, cattle, horses, poultry, dogs and cats. Symptoms include increased thirst, loss of appetite, and watery discharge.

f) **Pasteurellosis**

This disease affects humans, cattle, swine, rabbits, horses, chickens, several avian species, dogs and cats. The causative organism is *Pasteurella multocida*. In humans infection occurs at the upper respiratory tract, inflammation of the inner surface of the eye-lids, infection of the lower respiratory tract or bronchitis or pneumonia and infection of internal organs takes place.

g) **Pullorum**

This has been reported in humans. It is a bacterial disease caused by *Salmonella pullorum*, infective for chickens.

h) **Salmonellosis** (Food poisoning, gastroenteritis, paratyphoid, typhoid):

Salmonellosis affects humans and all domestic animals. *Salmonella* bacteria exist everywhere in nature.

i) **Gastroenteritis**

Intestinal infection or food poisoning is a most common manifestation of salmonellosis. The onset of the disease is usually sudden with headache, abdominal pains, and vomiting. There may be nausea, high fever, diarrhoea, chills, restlessness, muscular twitching and drowsiness. Faintness and thirst are often evident. The problem usually lasts for 2 to 7 days.

j) **Spirochetosis**

This bacterial disease is caused by *Borrelia anserina*. It affects chickens, ducks and pigeons. The main vector is a fowl tick, *Argas persicus*.

k) **Tuberculosis**

This bacterial disease, avian tuberculosis, may affect humans, chickens, turkeys, swine, cattle, horses, sheep, dogs and cats. Infection in humans is caused by *Mycobacterium tuberculosis*.

l) **Cryptococcosis**

This disease affects humans, cattle, swine, horses, dogs and cats. The disease is caused by a pathogenic yeast called *Cryptococcus neoformans*. Infection in humans begins as a primary infection of lungs. When the involvement becomes apparent the symptoms include cough, chest pain, weight loss, fever or dizziness. The disease may be in lungs, mucous membranes, bones, and joints. It

very frequently involves the brain covering as cryptococcal meningitis. The central nervous system involvement usually follows the pulmonary disease. Pigeon excreta is the most common source of *C. neoformans*. The yeast develops on the creatine (nitrogenous substance) in pigeon manure. The yeast is carried in the intestinal tract of pigeons.

m) Coccidiosis

Coccidiosis is a serious disease in poultry, cattle and sheep. The disease is caused by a protozoan parasite called *Eimeria* sp. of which over 500 species are known. Coccidiosis in chickens is usually associated with bloody diarrhea.

n) Toxoplasmosis

Toxoplasmosis may be one of the most widespread zoonotic diseases. It is caused by a intracellular protozoa, *Toxoplasma gondii*. It is extremely common in humans and can infect cattle, dogs, cats, turkeys and pigeons.

C. Wild Boar Borne Diseases

1. Health and Disease Risk

The wild boar is subject to many infectious disease. These include diseases specific to pigs (swine fever, foot and mouth disease, etc.). Wild pigs constantly exchange infections (a) with domestic pigs, (b) with other domestic livestock and (c) wild animals. Wild pigs contract infections more frequently than other species of wild animals, and since it covers large areas in its wanderings and migrations, it plays a particularly important part in natural disease, swine fever, pasteurellosis, erysipelas, etc. Further it is host to many parasites and plagued by a number of ectoparasites (ticks, pig lice, mosquitoes and gad- flies). The ectoparasites are also source of several infections.

2. Bacterial and Viral Diseases

Cross infection between wild pigs and livestock is frequent. The potential for wild pigs to harbour diseases transmissible to man or domestic animals is considerable. Cholera, swine brucellosis, trichinosis, and foot and mouth disease are all diseases that may be transmitted by wild pigs. From 1973-1977 there were 24 reported cases of trichinosis in humans in the U.S. that had been contracted from wild boars.

a) Brucellosis: A disease transmissible to man, occurs in feral pigs in South Carolina, Florida and Hawaii. Wild boars also serve for transmission of parasites and diseases to man, livestock and wildlife. Various types of bacteria can cause brucellosis. In pigs *Brucella suis* is the usual casual agent. Man may catch the disease by contact with infected organs of dead animals. Abattoir-workers, veterinarians, butchers and farmers are most at risk.

b) Foot and Mouth Diseases: This is a viral disease, highly infectious to cloven footed animals; cattle, pigs, sheep and goats are most frequently affected. The occurrence of the disease is characterized by vesicular eruptions in the membranes of mouth and the skin around the feet. The disease regularly affects animals (enzootic in parts of Europe, Asia, Africa and South and Central America) as the virus is easily transmitted by infected animals.

c) African Swine Fever: This is a viral disease specific to pigs. The risk of international spread of the virus is considerable. The virus is present in infected pigs, in the blood, tissue fluids, internal organs and all excretions and secretions of infected animals.

d) **Swine Fever**: Swine fever is also caused by a virus, it is prevalent in most parts of the world. The virus is transmitted by direct or indirect contact with infected animals.

e) **Vesicular Stomatitis**: This is a viral disease confined to America. This disease is clinically indistinguishable from foot-and-mouth disease. Mosquitoes and biting flies can also play a role in spread of the disease.

f) **Leptospirosis**: The disease is caused by various species of leptospirae. The disease infects dogs, cattle, pigs, sheep and goats and is transmissible to man. The bacteria invade the blood stream of affected animals and eventually become localized in the kidneys. While the infection is in the kidneys, the animal sheds large number of bacteria in its urine and this is the source of infection for other animals. The disease can cause death in young animals.

g) **Anthrax**: The disease is caused by *Bacillus anthracis* and affects a wide range of animals including cattle, horses, sheep, goats and wild herbivores. Pigs and humans can be infected. Feral pigs contract the disease by feeding on animals that died of the disease.

h) **Erysipelis**: The disease is caused by the bacterium *Erysipelothrix rhusiopathiae*. Infection in man can occur via wounds. There are various natural hosts for the disease including feral pigs.

i) **Tuberculosis**: Feral pigs are infected mostly by the bovine, avian or human types of tuberculosis. Infection by the bovine type, *Mycobacterium bovis*, is most common. Humans can be infected with tuberculosis by eating the inadequately cooked flesh of pigs suffering from the disease.

3. Parasites of Wild Pigs

Wild pigs are hosts for a number of internal and external parasites. Pigs carry sparganosis and hydatid cyst which can pose public health problems.

a) **Trichinosis**: This is caused by a parasitic round worm (nematoda), *Trichinella spiralis*. The main hosts for this parasite are humans, pigs and rats. Infection occurs by eating uncooked or inadequately cooked meat containing larvae (cyst- form) of the trichina worm. The cyst develops into worms in the small intestine. There the fertilized female worm produces new larvae which enter the blood stream of the host and eventually invade the muscles, creating new cysts.

b) **Sparganosis**: This is caused in pigs and humans by invasion of body tissues by the spargana of the cestode *Spirometra erinacei*. Pigs become infected by eating an intermediate host, such as frogs, toads, etc., and, in turn, man may acquire sparganosis by eating inadequately cooked pork.

c) **Hydatid**: Pigs may act as an intermediate host for the hydatid tapeworm, *Echinococcus granulosis*. The eggs of the parasite may accidentally be ingested by man. The resulting disease is considered as a most serious parasitic disease affecting man. The eggs ingested by the intermediate host (pigs, sheep, goats, ox or man) develop in the intestine of the host and penetrate the intestinal wall and migrate to a suitable part of the body, as liver or lungs to form a cyst.

d) **Pork Tape Worm**: *Taenia solium*. Man is the primary host for this tapeworm and pigs are its intermediate host. In the primary host the parasite attaches itself to the

intestinal wall and sheds eggs that are passed out and may be ingested by pigs. A cyst develops in pigs. When meat containing cysts is eaten by humans, the tapeworm develops in the intestine, and the cycle repeats itself.

4. Ecto-Parasites of Pigs

Pigs may become infected by the bush-tick, *Haemaphysalis bispinosa*, and sometimes can carry sarcoptic mange, *Sarcoptes scabiei*, and the pig lice, *Haematopinus suis*.

LAGOMORPH PESTS: BIOLOGY AND BEHAVIOUR OF PIKA AND DESERT HARE

By Abdul Rauf Khokhar

A. Pika or Collared Pika (*Ochotona rufescens*)

Description: The collared pika is a lagomorph, related to hares and rabbits. It has two pairs of incisors in the upper jaw, one pair behind the other. Pikas have no tail. They are attractive in appearance with soft silky fur of a reddish-grey color and furry rounded ears (Fig. 1). The under fur is dark blue-grey. The distinctive feature from which it derives its name is the presence of a paler sandy-buff collar of hairs just in front of the shoulders. Its feet and toes are well furred. The hairs, which almost completely cover the toes and soles, give them protection against the severe winter cold. Adults can weigh up to 300 g and measure about 190 mm in body length.

Fig. 1. The collared pika.

Distribution: Its distribution extends throughout the higher mountain ranges of central and northern Baluchistan including Ziarat and Fort Sandeman. They also occur in higher mountain ranges of Waziristan and upper Kurram valley (Fig. 2).

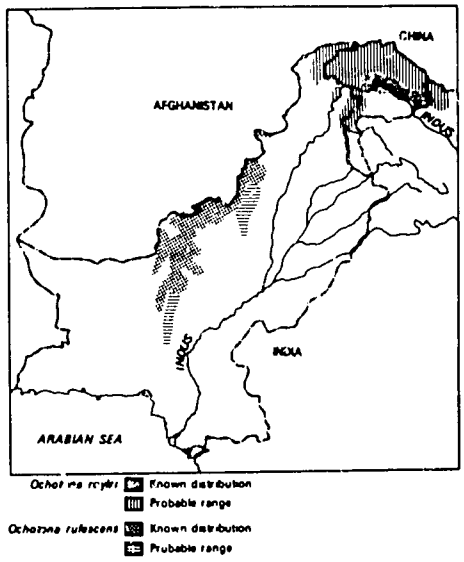


Fig. 2. Distribution map.

Habitat: Pika is associated with mountain steppe forest normally at elevations about 1300 m and even upto 4000 m. They occur in *Juniperus macropoda* forest as well as on the edge of patches of cultivation in the higher remote valleys and particularly favour stone walls and embankments surrounding cultivated areas.

Habits: Pikas are diurnal in habit. Inspite of living at high elevations and in severe winters, pikas do not hibernate. They live either in self excavated-burrows under juniper tree roots or in earthen embankments. Natural cavities, between rocks or stones forming the boundary wall of plots of cultivation, also provide habitat for them. Their burrows are quite shallow and seldom exceed 60 cm in length.

During the summer season these animals are active mostly during the early morning and early evening. During cloudy days they are active throughout the day and generally sun themselves by sitting on exposed rocks. They are herbivorous and live on a variety of food items. They, however, prefer stems and green leaves of various shrubs and grasses, including young wheat. During summer, collared pikas cut green vegetation and carries it to their burrows. Sometimes they leave fresh cut green materials at the mouths of burrows to dry before dragging them into the burrows.

Pikas inflict considerable damage to green wheat as well as fodder and vegetable crops. The most serious losses caused by this animal occur when they feed on the bark of fruit trees. This occurs mostly when winter snowfall covers the ground and green fodder is not attainable. During one of the surveys, 20% of all apple orchard trees were found damaged by pikas in Ziarat valley.

In some years their population density increases dramatically and apple orchards suffer severe damage due to their attack. There is some evidence that when a large number reproduce in a good year, there is heavy mortality in the subsequent winter when the harsh weather conditions and lack of green food results in a population crash.

The female has four pairs of mammae. They start breeding in March and can produce upto three litters during the period up to early October, having four to eight young per litter, the average being five young.

B. Desert Hare (*Lepus nigricollis*)

Description: The desert hare has very long broad ears and greatly developed long hind legs (Fig. 3). The fur is relatively short and harsh and is banded with pale cream and black. The belly fur is long, soft and creamy yellow in the chest and throat region. The ears are folded inwards on their interior margin and in bright sunlight are semi-translucent. The head and body length averages 480 mm (range 330-528 mm) with the tail averaging 77 mm (range 64-90 mm).

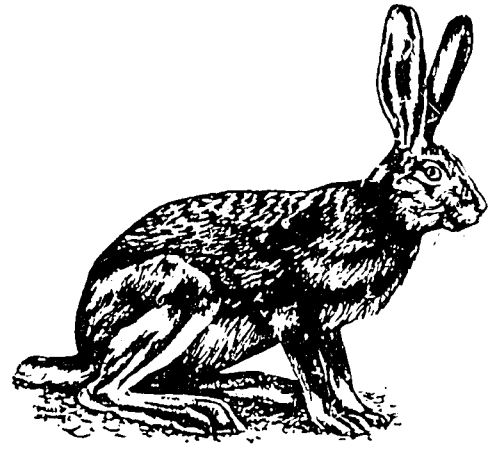


Fig. 3. The desert hare.

The position of the eyes on the head is very high up and far back so as to give the animal a wide angle of monocular vision. With this position of the eyes the animal can see the approaching enemy from above and behind without turning its head. Sense of smell, hearing, and sight are very acute in hares. They can rotate their large ears independently. They can run at a speed of approximately 50 km an hour.

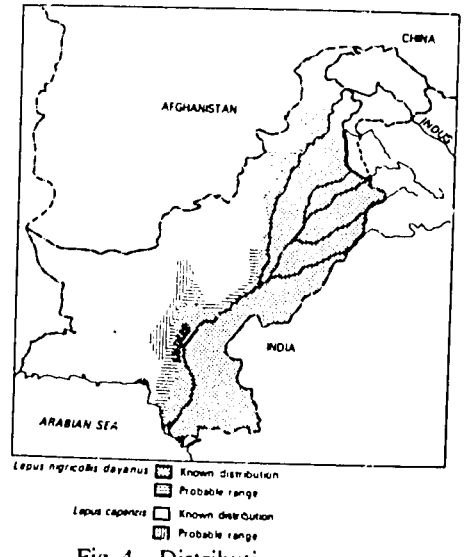


Fig. 4. Distribution map.

Distribution: The desert hare occurs throughout Sind, Las Bela, Sibi and the Punjab. It is also found in the desert regions of Cholistan, Thal and Thar. In NWFP, it extends through Peshawar and lower part of Kurram valley. It also occurs in Dera Ismail Khan (Fig. 4).

Habitat: It can be found in cropland through the Indus Basin as well as in extensive sand-hill desert. It ascends into low rocky hills in regions west of Indus as well as scrub forest in regions such as Salt Range. It does not, however, find permanent shelter in cropland but prefers waste lands on the border of cultivation. Its preferred habitat is in the uncultivated tracts of the riverine zones where there are extensive clumps of *Saccharum munja* grass.

Habits: The desert hare is a non-social species. It does not excavate burrows and normally shelters in the holes excavated by other animals. Usually it emerges to feed just before dark and is more active in the early hours of night, resuming a second period of feeding just before dawn. The desert hare grazes on grass roots when these are available. It also attacks the green leaves of different crops, such as chickpea, rice, wheat, etc. In groundnut fields it does not damage the plants or roots but paws out the nuts from shallow diggings and opens the shells leaving empty groundnut shells scattered among the plants.

Males remain reproductively active throughout the year. Young ones are produced only during spring and summer months. Most of the litters, however, are produced during early spring and at the beginning of the monsoon. These periods coincide with a more abundant food supply due to vegetative growth. Litters vary from 1 to 4 with an average of 2. The young are active and well covered with fur. They have comparatively large heads with relatively short ears. Females show post-partum estrus like rodents. But unlike rodents, the gestation period in desert hare varies from 42 to 44 days. Nothing is known about the age at which the hare attains sexual maturity. The sexual maturity in European hare however, is not attained until two years of age.

CONTROL OF AFGHAN PIKA AND DESERT HARE

By Ejaz Ahmad

roduction

The collared pika, *Ochotona rufescens*, is also referred to as mouse-hare, rock-hare or the ›ing hare" because they belong to the hare family. They are generally confined to alpine rocky ions of Baluchistan and Gilgit. The pika cuts, dries and stores forbs and grasses for winter use. ring winter in Baluchistan, they debark the apple tree trunks and this damage often kills trees or, in case of incomplete girdling, reduces apple production. Also, pikas damage winter wheat, maize and ato crops.

The desert hare, *Lepus nigricollis* is a large greyish-brown animal with long well developed s. The tail is short and tipped with black. The hind legs are elongated for a speedy bounding gait en running. It occurs throughout Sind, Las Bela, Sibi and the Punjab and also in the desert regions Cholistan, Thal and Thar. The desert hare is a minor pest of groundnut and chickpea in barani as of Punjab.

ntrol Methods

Various control measures can be adopted successfully to prevent the losses caused by omorph pests. These are described here based on the experience of the Vertebrate Pest Control ›ject, Vertebrate Pest Control Laboratory and knowledge available in the European countries. sically, the fundamentals of integrated pest management (IPM) are put into practice for control of se vertebrate pest problems.

Afghan Pika

1. Baiting

Pikas, being forb and grass feeders, do not accept grain baits except rolled cereals like oats. ›sh green bait like lucerne (*Medicago sativa*) is not too effective. However, apple chops are highly ›ferred. Baits with zinc phosphide (2%), when prepared with freshly cut apple pieces, can be ›ctive in reducing the pika population by 40 to 60%. Brodifacoum (0.005%) with rolled oats can e 90 to 100% mortality of pika.

Poisoned grain baits are placed in small piles of 10-15 g into the active burrows or nesting ces or into stone crevices and, in the case of apple fruit baits, one piece is placed at each bait site.

2. Protective Repellent Coatings

A sticky compound called "OSTICO" brand (ICI Product) or a specially prepared sticky paste ›eloped by Vertebrate Pest Control Laboratory, can be used for pika control. The basic ingredients this paste are rosin, paraffin wax and castor oil and is highly effective as repellent. It can be used ›ve the ground level and coating at least 45 to 60 cm of the tree trunk. This paste band will also ›tect the trees from crawling insects and provide protection to the tree trunks from fungal attack. als conducted a few years back in Ziarat valley have shown that these compounds effectively luced damage and had no effect on the normal growth of the trees. However, applying paste to dlings should be avoided.

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3. Indigenous Methods

Various methods have been used by orchard farmers in Ziarat valley areas, to protect apple tree trunks from pika damage. In areas where juniper forests are found, long strips of this tree's fibrous bark are stripped from their trunks. These are then wrapped around the lower trunks or lower branches of apple trees. This is a very laborious operation. This bark will provide total protection for the portion of the tree covered but pika can climb over the bark and feed on a higher uncovered portion. In addition to this, as the bark wrappings do not stretch, they must be removed each spring to avoid choking the tree growth.

Another form of protection is the use of twig bundles of a local *Aretemesia* shrub (worm wood) tied around the apple tree trunk. This banding is effective upto a height of 45-60 cm, about the maximum length of the twigs. In winter, when the snow cover is heavy, pika can climb over the twig bundles to chew on the bark of tree branches. One good point is that these twig bundles are elastic and can be left on for several years before they tend to choke the trees.

4. Tree Guards

Tree guards (e.g. vexar tubing) can be used to protect trees from pika damage. These cannot be used against voles to prevent underground damage.

Recently, Nippon Kohan K. K. (Japan) developed "Foil lath", which is like mesh net, to protect fruit trees against mice and rabbits. This consists of ultrathin (0.15 mm thickness) cold rolled steel sheet. The covering of the tree is done in the late summer and there is no need to remove them in the early spring as lath covering rusts and falls off the trunk, thus not inhibiting the growth of the trees. Another advantage is that the lath is cheaper than other plastic materials.

5. Other Possible Control Measures

In general, fungicides have some rodent and rabbit repellent action. Of these, Thiram, trade named "ARASAN", is the most effective, and is used elsewhere in the world as a rabbit repellent by painting it on tree trunks but this product has not been evaluated in Pakistan against pikas.

Reducing ground cover can be another alternate in the management of pika populations. Herbicides, such as atrazine or 2, 4-D can be used to reduce early vegetation growth. Low vegetation can also be reduced by disking or other mechanical means or even by burning. Providing alternate foods to pika in the winter months may be one method to prevent tree damage.

B. Desert Hare

1. Exclusion

Exclusion is most often accomplished by the construction of fences around the area to be protected. Woven wires of poultry netting should exclude all desert hare from the area to be protected. To be effective the fence must be of mesh not greater than 4 cm, 75 to 90 cm high, with the bottom 15 cm turned outward and buried at least 15 cm below ground level.

Exclusion by fencing is desirable for small areas of high value crops but most often impractical and too expensive for large acreages of farm land.

2. Poison

Both type of poisons i.e. acute and chronic can be used. Zinc phosphide (2%) or Racumin (0.0375%) can be applied on some baits. The best bait is carrot cubes but green leaves are also

acceptable. Prebaiting can be done. The baiting should be done between the field being damaged and fields where the hares normally live. Place pre-bait and bait around the edge of the field being damaged. Place 100 to 300 g of bait in areas visited by hares. Check the bait daily and add bait as needed.

A single feeding of zinc phosphide will control the hares but single feeding of anticoagulant bait will not control them. Anticoagulant bait must be eaten on five or more successive days. Bait should not be scattered in the crop.

3. Shooting

Damage may be suppressed or eliminated by shooting, where it is safe to do so. Effective control may be achieved using a spotlight at night when hunting.

WILD BOAR: IDENTIFICATION, BIOLOGY AND BEHAVIOUR

By Mohammad Hafiz Khan

A. Identification

The wild boar is a mammal which is a member of the super family Suidae in the order Artiodactyla, the even-toed ungulates. There are two families: the Suidae, or old world pigs, and the Tayassuidae, or Peccaries of the Americas. There are 8 species of pigs distributed throughout Europe, Asia and Africa. Out of these, the wild boar or *Sus scrofa* has twenty one sub-species.

The number of such species attributed by taxonomists to *Sus scrofa* has varied over time. The animal found in Pakistan, in the light of research done so far is *Sus scrofa cristatus*. The identification marks of this sub-species are a longer bulky animal with a very short thick neck, deep body and rather slender legs. The head has a long sloping muzzle terminating in a special flattened disk. Large ears are pointed and set forward, being thickly fringed with hairs. Small eyes are set far back in the skull close to the base of the ears. The short tail usually terminates in a tuft of longer yellowish brown lateral bristles.

The skin colour is dark grey varying to pinkish brown. It is sparsely covered all over with coarse black and brown bristles. Longer bristles on the nape and over the shoulders form a crest. The bristles on the cheeks are also longer and often a yellowish or horn colour. The head and body length varies from 115-160 cm and the tail length from 18-28 cm. In the year 1987, 117 animals were killed by gun shooting under USAID research programme at Faisalabad and the largest animal killed in Chak No. 195/R.B. Faisalabad weighed 135 kg (297 lbs) with 153 cm head and body length. A second animal killed in Faisalabad Airport weighed 118 kg (260 lbs) with 163 cm head and body length, 28 cm tail and 92 cm shoulder length.

Dumber Brander recorded the heaviest male as weighing 165 kg with a tusk length of 25 cm. In Pakistan no organized work on the bio-systematics of this animal has been done so far. In 1987, a research programme under USAID Vertebrate Pest Control Project was started and data for the comparative external morphometric of wild boars are being collected.

The data collected comprises: head and body length, tail length, hind foot length, shoulder length, snout length, snout to mid eye, cranium length, body weight, eye lenses, lower jaw, testes from male and ovaries from females. These data are to be compared with the measurements taken from wild boars from Poland, Czechoslovakia, France, Germany, Malaysia and the U.S.A. to determine how Pakistan wild boar may differ.

B. Biology

Wild boar are normally social animals, resting and feeding in small groups, though adult males will usually forage individually. The animal is sensitive to intense sun because the sweat glands are few. The boars spend the day in the densest cover near some water source.

When wild boars are disturbed, they give rapid low grunts and an adult male will clatter his tusks together in an audible and menacing manner when angry and about to attack. Their sense of smell is particularly acute and they find their preferred food by this means. Wheat , maize, groundnut and gram are subject to their depredation at two stages. The first attack occurs when wheat is freshly sown and until it sprouts. The wild boars will open dead-straight furrows with their snouts, eating all the grains deposited by seed drill, doing this so precisely that it is hard to imagine such parallel open

furrows were not made mechanically. They damage again when the ripening wheat and maize grains are at milky stage.

They have a strong, rather acrid, body smell which is especially noticeable when they have been lying up during the day. This body smell may be a factor in maintaining social contacts. Wild boars have long been recognized as dangerous and aggressive animals worthy of the huntsmans' skill. In 1986 at Faisalabad there were 15 separate cases of men being seriously attacked and three of these were killed. It should be mentioned that in 1978 wild pigs opened the grave of one freshly buried dead body in the village Gehrian near Gojra, District Toba Tek Singh. The villagers approached the writer and a well organized shooting party was arranged and 17 animals were killed from the graveyard of that village.

In the sub-continent of Indo-Pakistan, studies have shown that the breeding of wild boar can occur throughout the year but there is probably a peak breeding period before or during the monsoon season. In Pakistan most litters are born between April and October. Under the USAID Project, data collected so far reveal that out of the 32 females shot from August, 1987 to January, 1988 not even a single female was found pregnant. Oogenesis started in the month of December and January in most of the females. On January 10, 1988 first mating of wild boar was observed at 11:00 pm. at Faisalabad Airport. All females killed after January 1988 were pregnant except one, although in some cases there was very early pregnancy. The litter size as found during autopsy appears to be from 4 to 10 young ones depending upon the age of the female. In young females mostly there were 4 young ones but in the older females it ranged from 6 to 10. One very big female killed near Gutwala in June, 1971 showed 13 embryos when the hunters opened the belly out of curiosity. It has been also observed from the data collected from Faisalabad region that after littering, wheat grains are available to the piglets in the fields, followed by sorghum heads, millet ears, rice and maize at milky stage. The young of the litters of May and June 1987, after having a rich diet upto November, the females reached puberty in the months of February to March 1988. These findings will be confirmed in the next year's breeding season as these are not in conformity with earlier work where it has been mentioned that females reach puberty at the age of 1-2 years.

The gestation period ranges from 110-115 days. The females have an irregular number of mammae varying from 8 to 10, although 5 pairs are most normal. The female builds a rough nest by cutting grass, sugarcane stems, wheat plants etc., heaping this together. The young ones are born in this nest which usually is well concealed.

C. Behaviour

Wild boar is known to be a nocturnal animal but it has been seen moving about in day time, where there is no human disturbance. In lonely parts of the jungle the hunter often comes across several wild boars searching for food. Generally they wait for ceasing of human sounds for coming out. As soon as human movement ends with the coming of darkness, they are in the crops. Its tendency is to spoil much more than it could eat. An additional factor is that a flock of boars emits a peculiar smell onto the damaged plants such that no cattle would touch them even as fodder.

For its abode it need not go away from the cultivated fields. It does not require heavy bush to move in; for rest just a little prickly plant for shade and nearness of some water is enough. Although its tendency is to avoid human presence, yet it does not mind the nearness of a farmer when out in the crops. The poor cultivator may cryout or beat drums and it will go on marauding as if undisturbed. It will avoid a crowd but never mind a single worker. Its smell is acute, eye sight is weak, and hearing is moderate. Old tuskers have been found practically deaf but instinctively their reactions were as good as not being deaf. The general behaviour of its flock is not different from that of sheep, but there is always a lone tusker behind, who is generally a killer. He keeps a constant conduct of annoyance because of being deprived of female company by the intimidation of younger males. Another factor for his being peevish is that he must have faced a few strokes from a grass cutter or a farmer in the past.

This has given him hatred for humans. A dominant natural gift on him is courage, intelligence, and fortitude. Even tigers are said to avoid the mature furious adults. When a boar is chased from its habitat it will return to the same place the following night or a few days later. Its temper is capricious and, when wounded, may become savage and vindictive. It has been observed in the field that the boars single out white or blue-clad persons for charging out of hunting party. It does not lose spirit when cornered. If attacked by dogs or a man on horse back it behaves as if used to such fun. It reacts as a professional fighter. Mr. Dumber Brander of the Indian Forest Service in 1931 killed a well known killer. It bore several scars and was so ill tempered that it would charge any one to be seen and once the victim was down, went on giving cuts. One of his victims had 42 wounds on his dead body.

Let me tell you that I shot a wild boar in 1980 on the service road attached to the Gogera Branch canal leading from Jaranwala to Satiana. This boar attacked a beldar without provocation, namely Wali Mohammed, while the poor man had just sat down to eat his late morning meals on the canal bank. I was leading a shooting party in that vicinity. A man came on a bicycle to inform about the incident. I hastened towards the site, almost 1/2 mile to the north of the syphon. The man was lying unconscious and the boar was sitting beside looking towards the pedestrians who stood at a respectful distance, having blocked the road on both sides. The boar's over confidence gave me an easy target and he was down by one shot in the head. I fired with .12 bore gun using a nylon ball made by Seller & Ballot. The ball was 3/4 oz. in weight, backed by the standard 2.5 drams of smokeless gun powder. The distance was almost 30 meters. The beldar survived the attack, returning to his senses five days after.

DAMAGE PATTERN OF WILD BOAR IN DIFFERENT CROPS

By Iftikhar Hussain and Joe E. Brooks

A. INTRODUCTION

Throughout much of Pakistan the wild boar (*Sus scrofa*) is a major pest affecting agricultural production. Though omnivorous, they are largely vegetarian in diet. They will consume a wide variety of seeds, fruits, young leaves, tubers and succulent stems as well as fungi, carrion, bird's eggs, reptiles and insect larvae. It is also reported in Pakistan that wild boars damaged ripe sugarcane, potatoes, wheat (both newly sown grains and again at milky stage) and rice in the milky stage. Wild boars killed from riverain forests were subsisting mainly on roots and tubers of *Scirpus* and *Cyperus*, while crops such as sugarcane, clover, and mustard were found only in a few stomachs. Animal matter, such as insects, annelids, fish, snails and rodents, constituted about 10% of all stomach contents. The stomach contents of 48 wild boars killed in Faisalabad District were examined and it was found that wheat and molasses scum were the most common items, followed by *Cyperus* tubers, maize, sorghum, cotton, mesquite pods and leaves, sugarcane and rice. Animal remains consisted mainly of earthworms, snail, crickets and a few frogs, fish, rats, lizards, one bird and carrion. Wild boar are one of the most important vertebrate pest species in sugarcane, wheat and maize, while of lesser importance in groundnut. Their damage patterns in sugarcane, wheat, maize and groundnut are described here.

1. Sugarcane

Wild boar damage sugarcane by tearing away the rind with their incisors, on stalks they knock over or those already leaning over or on the ground (Fig. 1). The rind is stripped away from 10 to 50 cm lengths of stalk, and boars consume the soft juicy inner pith. Wild boar damage is easily differentiated from rodent damage by the presence of large pieces of rind; also the damage includes the nodes, which are rarely touched by rodents. Some damaged plants are seen on the field periphery but most occur in large patches in field interiors where the animals bed down during the day light hours and along pathways they use in coming and going from field interiors. Once damaged, the stalks usually wither and die. Farmers leave them in the fields because they report that these are useless as animal fodder as cattle and buffaloes will not eat the stalks because of the boar smell.

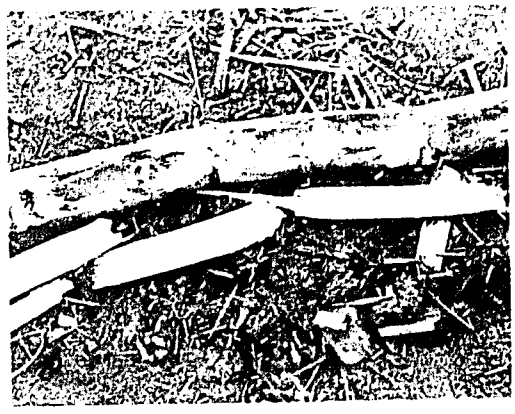


Fig. 1. Damage to sugarcane.

2. Wheat

Wild boar damage to wheat is of several kinds. The depredation is at two stages. When freshly sown and until it sprouts, boars will open dead straight furrows with their snouts, eating all the grain deposited by the seed drill, doing this so precisely that it is hard to imagine such parallel

Fig. 2. Wild boar damage to wheat showing the regurgetated fibrous material

open furrows were not made mechanically. Again when the ripening wheat grains are at milky stage, the animals make bedding areas in the field interiors by wallowing and then spreading cut stems to make a mat to rest upon. Stems are often trampled into the ground by wild boar activity. Ground surfaces are laid bare due to wallowing and rooting activities. Finally, the stems and panicles are consumed, the boars cutting them from 20 to 40 cm above ground (Fig. 2).

Fig. 3. Damage to maize cobs.

3. Maize

Wild boar begin consuming maize when the cobs have kernels in the milky stage. Stems are knocked over with the body or snout (Fig. 3). The kernels are consumed from the cobs and sometimes the cobs also are consumed if they are sweet and soft. Wild boar also trample the maize stems into the ground and damage can be found anywhere in the field.

4. Groundnut

The wild boar root out groundnuts from underneath the plants (Fig. 4), generally a depression from 5 to 10 cm deep and as much as 30 to 40 cm in diameter. Very few empty groundnut shells are found, since most nuts are consumed with the shells. The trail of the wild boar can sometimes be followed through the field from plant to plant. Some plants are uprooted and die, while others simply have the nuts removed but the plants survive. Wild boar prefer the groundnuts in the soft, fresh growth stage before the shells harden. Positive proof of wild boar is the finding of the foot prints in the field.

Fig. 4. Damage to groundnut.

5. Other Crops

Rice, potatoes, sweet potatoes, peas and clover are other crops damaged by wild boar. Wild boar eat the grain of rice while walking through the field. Potatoes and sweet potatoes are damaged by digging the ground with the snout. Peas and their pods are eaten from the plants. Clover is damaged by the animals digging in the ground.

B. Damage Assessment Methods

1. Picking the Fields

The selection of fields usually boils down to a randomized method of selection, which gives the least biased samples, or a road transect method. The randomized sample may be spread over a large area and this makes reaching all the fields difficult but is worth the extra time. The road transect method means a large number of fields can be sampled in a relatively short time. A third method is

the stratified random sample, where, for example, villages may be selected at random for visit, eliminating those that are difficult to reach by road. At each village, 4 to 8 fields are selected using the four compass directions from the center of the village and picking fields encountered while walking north, east, south and west. Usually using this method, 4 to 6 villages can be sampled each day, giving a total of 16 to 32 fields surveyed per day.

2. Methods in Fields

a) Sugarcane: Once a decision is made on which method to use, the fields are visited and the damage data taken. Damage in sugarcane, both rat and wild boar damage, tend to be clumped (Fig. 5). Wild boar use the field interiors and pathways in the field and this is where the most damage is seen. Likewise, rats tend to create most damage nearest their burrows, so this is where their damage is found. The best method to use to find damage in a field is to use transects crossing the field at several places. Samples are taken along the transect at a given number of paces from the field edge, making sure that some samples are taken near the field edges. The average distance between sampling points may best be determined in the field but as a guide, use at least 10 meters between points, perhaps more. Damage is recorded on a 2-meter sector of the line where it falls across the cane stalks. Search the area for rat-damaged stalks and record the number of damaged and undamaged stalks on the 2-m sector. Note the presence of rat burrows within or near the sampled area. Likewise, for wild boar damaged stalks, record the number damaged and undamaged. Since wild boar may be bedded down within the field interior, it is best to make these surveys in pairs of observers and it would be helpful for one person to have a shotgun loaded with shells of heavy shot or slugs as a precaution in case wild boar charge. Surveys for damage can be done when the damage first starts and cumulative damage may be recorded by visiting the same fields repeatedly for several times during the maturing phase. Or, if damage at harvest is to be estimated, visit the fields just before they are cut.

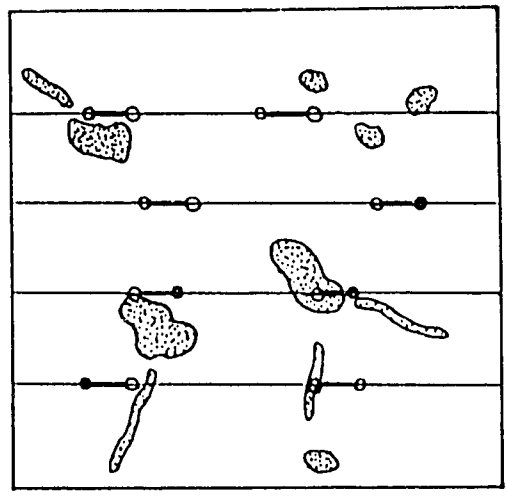


Fig. 5. Damaged areas in sugarcane fields and transect sampling points.

b) Maize: In maize fields, the damage may be found anywhere in the field. The use of transects crossing the field is again suggested, taking enough sampling points per field (4 to 6 are suggested) to cover the area well. At each sampling point, using a rope or piece of cord, lay out a quadrat of 5 by 5 meters in size and within this area count and record all boar and porcupine damaged stalks and all bird damaged cobs and all undamaged stalks and stalks with undamaged cobs. Generally two observers can do a field in this way in 20 minutes.

3. Damage Calculations

Percent damage for both sugarcane and maize is computed as number of damaged stalks divided by the total number of damaged and undamaged stalks times 100. In the case of boar-damaged sugarcane stalks, each dead or dying stalk represents a direct loss in sugar yield. Rat damage rarely kills the stalk and the loss in yield of sugar is computed as a percent of the damaged stalks, usually taking 32 to 43% of the percent of damaged canes as the loss in sugar yield. These figures were derived from regression equations between percent loss of sugar per acre and percent of rat-damaged cane stalks calculated for Jamaica and the Philippines.

In maize, the wild boar- and porcupine-damaged maize stalks represent a direct loss of yield, while the losses due to parakeets and crows can be computed by measuring the actual loss of kernels on the damaged cobs. This is done by measuring the rows of maize kernels actually eaten. The length of the cob kernel rows is measured and the number of rows per cob is counted. The length of the kernel rows eaten is calculated as a percentage of the total row-lengths of kernels present on the damaged cobs (Fig. 6). In the example shown, the total length of kernel rows is 7.0 cm x 12 = 84 cm while 8 rows x 2.3 and 1 row x 2.0 and 1 row x 1.5 = 31.9; damaged area 31.9/84 (total) x 100 = 38% damage to that cob.

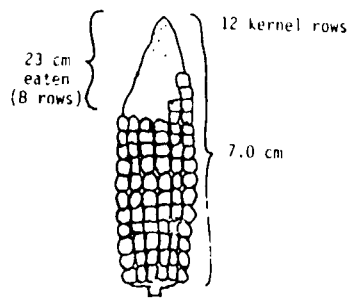


Fig. 6. Count total kernal rows and amount of kernal rows eaten to compute bird-caused maize losses.

NON-CHEMICAL METHODS OF WILD BOAR CONTROL

By Mohammad Hafiz Khan

Wild boar are of agriculture concern in Pakistan because of their current impact on agriculture, such as crop damage and wastage of canal water, threat to human lives, and in disseminating diseases. Damage occurs when wild boar walk through or camp in a crop, and when they eat the plants or grain both prior to and at harvesting. There have been reports of damage to sugarcane, maize, wheat, sorghum, potato and rice, etc.

There are nine methods of wild boar control, i.e., poisoning, pig sticking, trapping, shooting, fencing, netting, explosive bomb, hounding and habitat destruction. Wild boar poisoning has been discussed in a separate paper. The other methods are discussed as under:

A. Pig Sticking

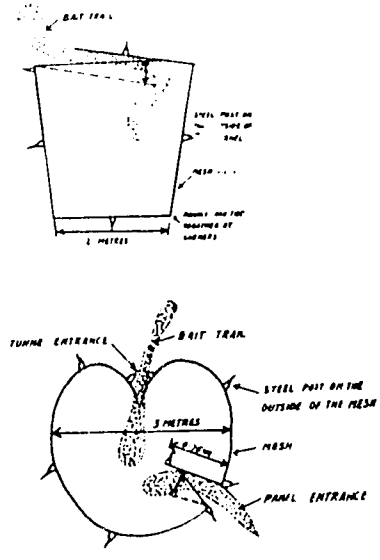
Apart from the need for wild boar control, pig sticking is an appreciable game. Utmost fun is enjoyed by the sportsman on horse back with a spear. The pig continues to charge back on the running horse and often inflicts disabling wounds on the legs and stomach of the charger. So, pig sticking is a game not to be lightly taken. Experienced riders and veteran horses could only bear the brunt of the game. The pig hardly feels fatigue in a moderate run. Mostly its courage gives a chance to the hunter. Having felt desperate of an unending chase it will turn back to hit the nearest horse, at the same time avoiding the sparkling blades of a number of spears. At this juncture the horse is saved only by an experienced hand. Amateur riders and freshly trained horses often yield casualties. If an experienced rider does not come to the rescue, a new hunter is bound to lose his limbs and his horse. No amateur should attempt to chase a wild boar single-handed. In district Sargodha alongside the river Jhelum and Chenab, wild boar chasing on horse back with a lance in hand is a pet game and horsemen from the country side have a passion to take part in such sport.

B. Trapping

Trapping can be an effective means of reducing wild boar numbers. There are four types of traps: 1) A panel trap, 2) Silo trap, 3) Double spring trap, and 4) Double spring trap with spikes.

1. A Panel Trap: Steel bars are placed on the side of centre of each panel, except the traps gate. The corners of the trap are held together by wire. The trap door is tied, at the top, to the wall of the trap.

2. Silo trap showing two entrances. Normally only one entrance is built; two are shown to illustrate alternatives. The entrance is formed by the two ends of the mesh springing together. The ends are tied at top with wire and rope. The boar forces the bottom of the ends apart and once in the trap, the ends spring back together.



Panel and silo traps.

Panel entrances: one panel is fixed, the other can swing out at the bottom as the boar pushes in. The top of the swinging panel is tied to the fixed panel.

In traps 1 and 2, if properly built, 12-15 boar can be caught in each trap each night. If trapping is to be used, it should be undertaken prior to sowing the crop, when green feed is scarce. Once a crop is in head, trapping is not successful, as the boars will not eat the bait.

3 and 4. These two steel jaw traps are of the same type and in this trap one animal is trapped at one time. In the first case animals upto a weight of 50 kg can be trapped as the heavier animals may leave a part of the limb and break away. In the second case even heavier animals can be trapped. In this case the animal will not be able to escape as one leg is trapped in the spring and two spikes enter up to 8 cm into the animal's body from lateral sides.

Successful trapping depends on the boars acceptance of the bait. It is important to offer the boars plenty of free bait prior to trapping. The best bait is wheat, sorghum, rice, apples, oats, and breads, etc. Spread the bait inside the trap and trail the bait for 10-100 meters out side the trap.

C. Shooting

Unless shooting is extremely intensive it is only effective on a small population where the boars are accessible, such as in regions with a few watering points. A variety of weapons are used to shoot the wild boars. Large calibre bullets such as .308 are best at long range but only small calibres or shot guns are needed at short range. In the peculiar conditions of our country side where cultivation is all the year round and the farmers are working in the field through out the day, use of rifle is held to be dangerous. The double barrel shot gun, preferably .12 bore, is the best to use. It provides an instantaneous second shot. Buckshot like LG, SG, SSG and one Ball cartridges are deadly effective within 40 yards.

The wild boar leaves four basic forms of signs for the benefit of the hunters.

a) Their deep, boxy tracks are found in soft soil and mud near feeding, bedding and watering areas, allowing houndsmen to start the chase or still hunters to plan a strategy. Dogs are useful to flush boar from areas of thick cover.

b) Their soft dung is found every where in mesquite plantation and other feeding grounds as another sign of their presence.

c) Large dishes and mud holes betray where these water-loving animals have wallowed in creeks. Spring and water holes are another solid indicator of boar activity.

d) Perhaps the most easily located of these are rooting patches where boar have rototilled the soil with their shovel-like noses in search of subterranean foods. Wild boar leave plenty of signs a hunter can use to his advantage

Wild boar are best shot through the shoulders to anchor them quickly and destroy their vital tissue. A close second is a shot low through the ribs directly behind the shoulder, especially if a shot angles forward and breaks the shoulder. A boar generally has enough fat to prevent abundant external bleeding, so hits in the abdominal and high chest cavity often allows the animal to escape into dense cover where locating them is next to impossible. A wild boar that does not drop immediately should be hammered with a backup shot until it falls.

Shooting from helicopters has proved successful in removing wild pigs from inaccessible areas such as swamps and marshes. In Moree region of New South Wales 516 pigs were killed in an area of 11 sq. km. in 5 hours at an average cost of $ 1.57 per pig. In our country wild boars were killed

successfully from the river banks and marshy areas in 1987 with a helicopter but my experience is that in irrigated forests and mesquite plantations killing is extremely difficult due to thick cover of the trees.

D. Electric Fencing

Electric fencing has been used in some area in order to protect the crops, but this method is still under investigation. The main consideration in electric fence design for wild boar is the arrangement of the live and earth wires i.e., the type of insulators used and the earthing arrangement. Generally the wire used is 2 mm or 2.55 mm high tensile wire.

In fences with hardwood posts and no steel posts, existing wires can be electrified. One design is: the bottom and the third bottom wires live and the second and fourth wires earth return connected. In dry soil conditions, it is essential that wild boar contact both the live and earth wires simultaneously for the fence to be effective. One extra wire can be added nearly at ground level and used as an extra earth wire. In dry soil conditions it is necessary to use extra earth stakes along the fence to ensure adequate earth return. If there is an existing fence with steel posts, an extra, electrified wire can be added. This is located on the outside of the paddock from which the boar are to be excluded. The wire should be 15 cm off the ground and 15 cm out from the existing fence, held in position by stand off insulators of creosote-treated hardwood posts driven into the ground. This arrangements is better with ringlock fences, which boar cannot easily get through. The existing fence is earth return connected. All paths or tracks under the fence must be blocked with logs or sticks that have been tied to the fence with wire to prevent the boar moving them. All tall vegetation under the fence needs to be cleared to prevent it from shorting the fence.

In 1979, the Punjab Government also provided generators to the Forest Department for fencing. However, this method could do more harm than good. Many useful species of wildlife, such as blue bull, hogdeer and Indian gazelle, were killed. This was obviously experienced in Chakku Forest, District Faisalabad. In addition to these animals, many deaths of human beings and domestic animals were also on record. The ratio calculated after installation of the electric fence at Chakku Forest was almost 100 wild boar, 10 domestic animals and one man.

In 1987 farmers of Chak Chatha and Maqboolpur in District Toba Tek Singh set electric fencing towards the side of a marshy area. They killed 26 wild boar and were able to protect the rice crop from wild boar by this method.

A suggestion is to be submitted that while fencing, a nearby channel must be dug with standing water in it. This will make the hooves of the animals fully conductive after having been dipped. It will, therefore, give much better results.

E. Netting

Netting is also used in this country. In areas beyond the river Indus, nets are used to catch the boar. Having been caught, they are tied with ropes then bull terrier dogs are let loose to see the game, if we can call it a game. I have tried a nylon net and caught a pig weighing 50 kg. This method can be used on a small scale to collect animals for experimental purposes. On large scale it is not feasible. In North Queensland, netting fences have prevented feral pigs from damaging sugarcane crops.

F. Explosive Bombs

I must admit that explosive bombs are a cruel part of the transaction in question. If this device can bring immediate death to a creature any explosive can be counted as a graceful and easier means of eradication. Unfortunately, it is not so.

Only small balls can be made. These are to be placed on tracks at dusk with an express caution to be removed before dawn in order to avoid any apprehending harm to the livestock. Small, because the temptation to be given is for eating. Any other type will not do. Our need is to avoid injured boar.

We have experimented with the following formula: Potassium chloride and sulphur are mixed in equal quantity. Before this, each is ground separately. Some glass dust is then mixed in, to accelerate friction and assure the mixture to be inflammable. About a dozen iron pieces are added. All this is covered in flour dough in the shape of squash balls and these are dried in the sun. A covering with full cream dry milk powder or cyperus powder, sex pheromones can be added.

This coating will serve as an attractant. The harder the ball, the more the pressing with jaws and more readily it will explode, scattering away teeth, tongue and jaw bones, thus practically shattering its mouth. The ensuing shock is immeasurable. The resulting haemorrhage and inability to drink and eat is bound to make him die in a few days. And during these days it shall not do any harm to anyone. Its mouth weaponry is its tusks and snout and the mini bomb will remove them. The surviving boar will be a mouthless goat ready to die any time. This device has an advantage. The number of victim boars will be exactly counted due to the exploding sound.

G. Hounding

In our cropland where riding is not possible, the wild boar is hunted more favourably with the hounds. A pack of various breeds of dogs is collected and a noisy track hunting starts with a little discipline. The sco.e is scarce but there is a lot of fun. If instructed properly, the dogs could do better. Most dashing dogs often fall victim to the wild boar. I have seen half a dozen bull terriers being struck one after another by a single boar which was ultimately brought down by a gunman. Keeping that in view we use a bull terrier and a greyhound cross-breed. A pair of one each will not let the boar escape and at the same time will not allow themselves to be hurt like their blindly courageous sires.

H. Swine Fever Virus

In 1967, an experiment was made in our area. A team from Veterinary Department was deputed to use some virus and netting was arranged through a local chairman in Chak No. 45/G.B. That gentlemen caught a few piglets by using a net borrowed from the fishermen. These piglets were inoculated with swine fever virus and the sickness prevailed. There was seen some population scarcity. But next year, it was reported that the swine had become immune. The Sartaj Sugar Mills got the services of Seth Sarwar, a renowned veterinarian. Despite repeated efforts, he found the virus was no longer effective. Anyhow, inoculation was stopped on a protest made by FAO. They were perhaps approached by the neighbouring country, where the swines are now a commercial property.

I. Habitat Destruction

In some areas wild boar are dependent on areas of thick vegetation such as reeds and mesquite plantation for shelter and hiding places. Villagers should be encouraged in doing away with these. Reeds and mesquite are useful to the common folk who are always in bad need of fuel and some kind of wooden substance to use in roofs. In some areas, swamps and marshes with typha growth have become permanent hiding places. These could be cleared up by installation of tubewells and some drain canals. This is being done on government level and some swamps are being minimized. If such abodes are eliminated, the boar would have to seek shelter on river banks. There the young one will be exposed to predation by jackals and wolves. This is bound to diminish their populations.

CHEMICAL CONTROL OF WILD BOAR

By Mohammad Hafiz Khan

The wild boar not only plays havoc with crops like maize, sugarcane, rice, groundnut and potato, etc. but constitutes a menace for human life and safety as well. Instances of attack on farmers resulting in serious injuries and even deaths are not uncommon. Heavy infestations of wild boar have been responsible for reduction in area under maize cultivation, and, near rivers and jungles, reduction in sugarcane cultivation, thus adversely affecting the agricultural economy.

Many control methods have been tried all over the world, in countries where wild boar are economically a serious problem for agriculture. Out of all these, chemical control is an effective method of quickly reducing the wild boar population. It is better if this method is used in conjunction with other methods that provide follow up control work. For effective wild boar control it is essential to know certain facts about boar biology - what the animal eats (so a good bait can be chosen), what area they roam (so control work can be done over a large enough area), how quickly they breed and die (so any gains by reductional control are not quickly lost), and what areas or habitats they prefer (so that most of the boar can be found and killed). Prior to 1978, endrin and parathion baits were used in Changa Manga Forest against the wild boar but these did more harm to other useful wildlife than to wild boar. Therefore, the poisoning programme, which was under the control of Forest Department, was discontinued. After that, successful experiments were conducted by Vertebrate Pest Control Centre, Karachi and University of Agriculture, Faisalabad. Now, poisoning has been shown as an effective method of wild boar control.

There are several poisons which kill the wild boar. The poisons which have been used in Pakistan successfully are:

1. Sodium Monofluoroacetate (1080) and Fluoroacetamide (1081)
2. Aldicarb (Temik)
3. Phosphamidon (Dimecron 100) and Carbofuran (Furadan S.T. 35%)
4. Arsenic Trioxide
5. Zinc Phosphide
6. Strychnine
7. Anticoagulants (Warfarin, Coumatetralyl)

1. Sodium Monofluoroacetate (1080):

Sodium monofluoroacetate is a white tasteless odourless powder, highly soluble in water. It is readily absorbed through the stomach. 1080 blocks the use of glucose in the body thereby reducing the energy. Death in animals results from either heart failure or depression of the central nervous system. To the technical material of 1080, a warning colour is added.

For the preparation of baits, 25 grams of 1080 dissolved in 5 litres of water are mixed with 75 kg of wheat grains. Before putting this bait at the baiting station or baiting point, 3 to 6 days of prebaiting in newly dug furrows is very important in order to make sure boars are coming to the spot. This method is no doubt very effective with high mortality of the boars, but the risk involved is that poisoned grains are spread all over the area as the animals move. The affected boars start vomiting. These poison grains cause hazards for useful wildlife and grazing cattle.

Moreover, farmers want a single dose poison without prebaiting for three to six days, which to them is an expensive and laborious job. This method has been improved and the latest method of encapsulation is adapted as it has many advantages over the other. Capsules containing 50 mg to 60 mg

of 1080 with 100 mg of Plasil are put in to flour dough of squash ball size. These balls are dusted with full cream dry milk powder, or dried ground cyperus tubers, or sex pheromones are placed at the animal tracks or where presence of animals is suspected. This method can be used even for a single animal in the sugarcane field and is less expensive, less laborious and safer for the user.

2. **Aldicarb (Temik)**

Aldicarb (Temik) was first used by the writer in 1978 after conducting a series of experiments on poisons and food preference of wild boar. For poison baiting against wild boar, heaps of boiled maize weighing approximately 1/2 kg are put on the tracks of wild boar or on the sides of water channels of crop fields. Each heap is covered over with 15 - 20 grams of Temik and 50 gm of full cream dry milk mixed with powder of cyperus tubers and brown sugar. This simple method is used by most of the farmers themselves in Punjab. A second method of using Temik is that it is dissolved in acetone and, after filtration, the filtrate is dried by putting the container over a sand bath. The dried material is 100% aldicarb which can very easily be used in the 100 mg capsules in the same manner as we have used 1080.

3. **Phosphamidon (Dimecron 100) and Carbofuran (Furadan ST 35)**

Mammalian toxicity of Dimecron is 26 mg/kg weight and that of Furadan ST is 14 mg/kg weight. These poisons, which are in a liquid form, are absorbed in wheat bran or gram flour. Gram flour or wheat bran is dried under shade for a day or two. Then the material is filled in capsules of 500 mg. It can very safely be used in flour dough balls. This powder can also be used with boiled maize, guava chips and in molasses scum. It has been observed in the field that there is quick knock down of the animal, like occurs with Temik, and the animals which have taken a lethal dose can not go a long distance, seldom more than 200 yards. The tendency of the farmers is that they demand those poisons which give quick results and they can observe the dead animals with their own eyes. In case of 1080, although a very strong poison, it does not show an immediate knockdown. Therefore, farmers are demanding other kinds of poisons.

4. **Arsenic Trioxide**

Arsenic trioxide is a relatively cheap poison and is easily available anywhere. A 1/2 tea-spoon quantity of powdered material is sufficient to kill a wild boar of any size. I have used arsenic trioxide mixed with molasses scum. It does kill the wild boar but there is no quick knockdown. An animal taking a lethal dose of arsenic trioxide can travel a long way before it dies.

Arsenic trioxide was also used successfully for the control of feral pigs in Australia using carcass which were dusted with 2 oz. of poison by giving cuts on the body. These were put on the tracks of the feral pigs. In the second case, apples were used as the bait. After 5 - 6 days prebaiting, apples were bored through by using a cork borer and 1/2 tea-spoon of poison was filled in. The hole was filled with the pulp of the apple. This method also worked in the eradication of feral pigs in some areas of New Zealand.

5. **Zinc Phosphide**

Zinc phosphide is a good rodenticide and this can also be used against the wild boar with success. This poison has a garlic-like odour and strong taste, therefore, it cannot be used like 1080 or Temik in bait. This poison was used in capsules of 500 mg quantity and then such capsules were put in flour dough, guava, apple or in cobs of maize at milky stage. The response of the animal was quite reasonable. In this case shyness in the animals is developed if the bait is not changed every time. It was also observed during use that poison gave colour and some odour to the flour balls. To overcome this difficulty the capsules are dipped in paraffin wax of very low melting point.

6. Strychnine

Strychnine is one of the alkaloids processed from raw dried seeds of *Strychnos nux-vomica*, a small tree native of India, north Australia, Viet Nam and Sri Lanka. The seeds were used for killing dogs, cats and birds at least as early as 1640. Its toxicity for hogs is 10 mg/kg weight.

This poison was used in capsules of 500 mg and three such capsules were put in flour dough balls with a coating of attracting material. This poison is very costly as compared to other poisons of the same grade. This poison has not been found very effective in the field, therefore, its use is not recommended for wild boar control.

7. Anticoagulants

Since 1950, great advances have occurred in mammal pest control. This has been due to the introduction of anticoagulant rodenticides. Anticoagulants kill wild boar in a manner radically different from acute toxicants. Their action is cumulative and they must be consumed over a period of several days to be effective. Anticoagulants inhibit one of the clotting factors in the animal's blood, with the consequence that the animal bleeds to death from massive internal haemorrhage. The anticoagulants possess two main advantages that acute poisons lack:

a) Anticoagulants do not produce poisoning symptoms that cause feeding to stop before a lethal dose is consumed by wild boar. Thus they avoid sub-lethal dosing and hence bait shyness.

b) The hazard of the poison to non-target species is greatly reduced and if accidentally any poisoning to man or domestic animals or non-target animals does occur, an effective antidote, Vitamin K_1, is available.

There are many anticoagulants like Warfarin, Fumarin, Pival, Diphacinone, and Chlorophacinone. Warfarin and Racumin have been used on a large scale against rodent pests in Pakistan. Last year the Vertebrate Pest Control Project, NARC, used anticoagulants in a preliminary field trial in Fateh Jhang area, resulting in high mortality of the wild boar. Anticoagulants can be used in the form of baits like other poisons in the concentration of 0.025 to 0.05% or in water solutions. Anticoagulants need several days treatment to be effective. Farmers are busy around the year, and generally they do not have the time for a lengthy treatment with anticoagulant baits. Field experiments with anticoagulants are underway, however, since they are relatively much safer to use than are most of the acute toxicants.

PRINCIPLES OF ORNITHOLOGY

By Joe E. Brooks and Iftikhar Hussain

A. Characteristics of Birds

Birds are unique animals, adapted to a wide range of habitats while retaining basic characteristics which make them recognized as "birds". Like mammals, they are warm-blooded.

1. External Features

Birds are the only animals to possess feathers. Feathers are derived from the epidermal scales of reptilian ancestors and have adapted to a variety of functions: flight, insulation, display, camouflage, water-repelling, insect-catching, etc.

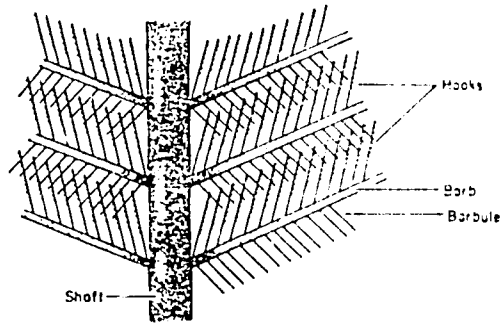


Fig. 1. A close-up look at a feather.

The structure of the feather is very simple. A feather consists of a main shaft from which the barbs arise (these make up the vane of the feather). From each barb there arises barbules, both forward and backward (Fig. 1). Each barbule has a series of hooklets which attach onto the flanged edge of the barbules on the next adjacent barb. The barbules, with their hooks, act much like zippers. This mechanism gives the bird a structure which affords lightness (the shaft is hollow), flexibility and air-worthiness.

The birds' body has been streamlined so it is aerodynamically efficient. This is done by the feathers overlapping and smoothing the angular air-resistant surfaces. The feet also can be withdrawn into "bays" when in flight.

2. Internal Features

Birds achieve lightness internally also. They have lost their teeth and the heavy jaws needed to support them. Instead, birds have a beak which is composed of bone overlain with horny keratin. The beak is hollow and the whole head is relatively lightweight. The skeleton has been reduced by a hollowing, thinning, and flattening of the remaining bones. The intestine has been radically shortened and the urinary bladder has been eliminated. There are air spaces in the bones, body cavity, and elsewhere.

Since birds have no teeth, the digestive system must accommodate with a grinding mechanism. Food swallowed whole is stored in the elastic crop and released into the muscular gizzard, which performs the same function as human teeth and stomach combined. Birds swallow small stones so there will be some abrasive material in the gizzard.

The body has been balanced by positioning all locomotor muscles toward the bird's center of gravity-leaving the wings to be controlled by tendon-like strings. Wings and legs contain relatively little muscle. Body organs are gathered in a mass in the center of the body.

Birds have large eyes and a wide visual field with remarkable distance determination, and by a brain with greatly enlarged visual and locomotor centers. This gives birds excellent visual acuity and rapid control of muscular reactions.

Breathing in birds is accomplished in flight and at rest by the contraction movements of the pectoral muscles. There is no diaphragm muscle as in mammals. The lungs of birds are very dense and relatively small; extensions of lung tissue permeate long bones and some body cavities. These air sacs add to buoyancy and also help regulate body temperature.

B. Classification of Birds

Birds are classified on the basis of the possession of certain external and internal features. The Class Aves (birds) includes all those warm-blooded animals with a four-chambered heart which have an external covering of feathers. Other features of the class include a hollow bony beak with horny covering, scaled legs with (usually) four functional toes with claws.

There are presently accepted 27 orders of birds. Those orders most important in vertebrate pest management in Pakistan are:

Columbiformes:	pigeon-like birds
Psittaciformes:	parrot-like birds
Passeriformes:	perching birds (this order includes many of the pest species, such as sparrows, larks, bulbuls, finches, mynas, weavers, starlings and crows).

We are interested in two other orders of raptorial and scavenging birds because they may become secondarily poisoned by eating rodents or other animals that have fed upon toxic pesticides. These are:

Strigiformes:	owls
Falconiformes:	vultures, eagles, kites and hawks.

C. Reproduction and Development

1. Mating and Nesting

Mating varies from promiscuous copulation and little parental care to high degrees of parental care and of individual birds paired for life.

At one end of a continuum are some kinds of fowl which bury their eggs in places like compost heaps, which heat up and incubates the eggs. The young, upon hatching, are precocial and able to gather food for themselves. Other birds mate together for periods of several years or for life, even though they may not remain together during the non-mating period. They return to the same breeding areas each year, mate and build the nest together. After the eggs hatch, the young are cared for by the parents until ready to fly.

Nests vary from simple depressions in soil or gravel to elaborately woven structures swinging from tree branches. Woven nests may be solitary or communal. Weaver birds commonly make their nests together, with many hanging from one tree.

Nest building is a stereotyped behavior of birds. Materials gathered are usually typical and specific for each bird species. Also the placement of the nest is species-specific. Some may nest in crotches in trees, some in grassy depressions on the ground, while others prefer cavities in trees or holes in cliff banks.

2. Eggs, Egg-Laying and Incubation

Eggs are laid in the nest, usually one at a time, one each day for several days, until the number of eggs for the particular species is reached. This number of eggs is known as the clutch size for that species. If one egg is removed daily by a human observer before the optimum number is reached, the female will continue to lay one egg each day for many more days before quitting.

Birds eggs are unique structures. They are incubated by the heat of the parent birds, except for a few gallinaceous birds. The germ cell is suspended upon the yolk and enclosed in albumin. The yolk is suspended by white chalazae, which are ribbons anchored in the egg white. Chalazae keep the germ cell upright even when eggs are turned, nearest to the body heat of the incubating parents (Fig. 2).

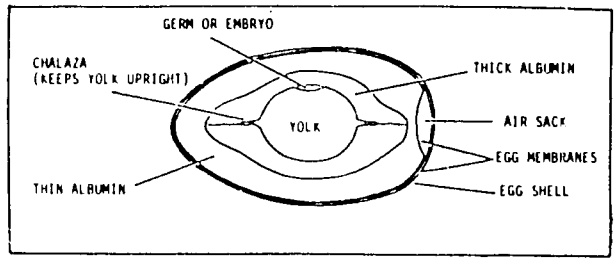


Fig. 2. A bird egg.

Incubation is accomplished when eggs are in contact with bare skin of the parent birds. Bare skin is produced either by plucking the feathers from the brood area or by the ruffling of the feathers away from the brood area. Generally the lower breast area becomes reddened and infused with blood so that the temperature approximates the parents' body temperature (often 100 degrees F. or more). Brood patches are pressed directly against the egg shell surface. Incubation time is highly variable and even varies within a species when there are environmental changes. Generally in passerine birds it averages about 12 days; larger birds have been known to incubate up to 80 days. As a rule, birds which hatch fully developed (precocial) young have longer incubation times; those which are altricial (hatch bare-skinned and eyes closed) and rely on the parents hatch sooner, but must depend on the parents for an additional time period - a week or two.

3. Parental Care

Parental care consists of feeding, warming, protecting, cleaning, and instructing the young. Parents feed the young with a variety of materials. Passerines often collect high protein insect larvae, which they feed whole to the nestlings. Other parent birds permit the young to have access to their crop, where the young may get partly digested food.

Altricial young are brooded beneath the parent birds when nights are cool. Since their feathers are not fully developed and they have not developed the ability to regulate their own body temperatures, this is essential. Precocial young are also brooded, probably more for protection than for warming.

Protection of young may take several forms. Males may exclude other species besides their own from their territories by aggressive actions. Other species may defend only the immediate nest. Protection may be direct, such as attack with beak or claws or the defecating by gulls on humans when nearing a nest. It may be indirect as when a mother plover feigns injury of the wing to lure potential predators away from the nest area.

D. Behavior

1. Migration

Migration is the regular, cyclic or seasonal movements of large number of birds from a breeding ground to a wintering ground or vice versa. While we understand some of the reasons why birds migrate, there are still many reasons for migratory behavior that we do not know.

In general, migration occurs along a north-south axis. This is especially true in the Western Hemisphere. In the Old World, however, there are more examples of southerly movements by way of eastward or westward pathways. It is thought that birds travel such zig-zag routes to avoid crossing large bodies of water (Mediterranean Sea), or deserts (Sahara) or mountains (Himalayas). In contrast, many of the migrants moving between North and South America have only to cross the Gulf of Mexico and the Caribbean.

Migration patterns vary. Some species move in large homogeneous flocks; others in highly organized flight patterns (geese). Still others move in along a broad front.

Movement of birds appears primarily related to day length (photoperiod). The lengthening days in late winter stimulates the sex glands. This brings on a restlessness and the birds begin more feeding to increase their body weight. Northward migration is coordinated with movement of weather frontal systems. In spring, birds await low pressure systems which bring southerly warm fronts. Migratory flights proceed most rapidly behind an advancing warm front.

In autumn, the sex glands have grown smaller, decreasing the territorial distance individual birds maintain toward each other. This permits flocking species to become integrated into organized flocks. As polar air masses come southward and cold air fronts precede low pressure systems, birds fly off in a southerly direction.

There is general agreement that migratory birds have the ability to orient using a compass. The more familiar orientational cues used by birds for simple compasses are the sun, the stars and the earth's magnetic field. The position of the sun in relation to the birds' biological clock (circadian rhythm) provides compass information and the position of the setting sun can be used by nocturnal migrants as a compass at about the time they begin their nightly flights. There is abundant evidence that the stars function as a simple compass for birds. Time compensation is not required because the star patterns can provide directional information. For example, Polaris, the North Star, is always to the north in the northern hemisphere. Finally there is increasing evidence that birds can detect the earth's magnetic field and use it to direct themselves along a north-south axis.

2. Territory

Any area defended by a bird against individuals of its own species is *territory*. Most bird species show at least some type of territorialism. Territory is roughly classified into *breeding territory* and *nonbreeding territory*. Breeding territory is used for the mating, nesting and feeding area for the young birds and their parents. This is the commonest type. Some species have only a mating and nesting (but not feeding) area. Others use a mating area only, maintained apart from the nest.

Nonbreeding territories are oftentimes feeding areas outside the breeding territory but which nevertheless are defended. Some areas may be defended in the winter months, particularly by permanent-resident birds that may or may not use the same territories during the breeding season. Some other species have roosting areas, specific sites used for night roosting. Some bird species will defend such areas.

Male birds usually establish the breeding territory, advertise this to other birds of the same species and defend it against males of its own species. Females may or may not participate in defense of the breeding territory. Methods used to establish and defend territories involve agonistic behaviors - threat displays, physical encounters, appeasement displays, pursuit-flying and singing or other vocalizations.

E. Bird Populations and Their Regulation

1. Longevity

Birds have a capacity for longevity in captivity of around 20 to 30 years. But it is not common for birds in the wild to live to this age. Birds are subject to a great variety of environmental factors which shorten life span: diseases, parasites, predation, unfavorable weather, competition, and accidents, etc. As a rule, the larger the bird, the longer it is likely to live.

2. Bird Numbers

How many birds are there? Nobody knows with any certainty. One expert placed the numbers at 100 billion but it could be higher. Only two countries have tried to count their bird numbers. In Great Britain, from bird censuses in selected habitats, the number of breeding land birds totalled 120 million. In Finland, the total number of birds was estimated to be 64 million.

Probably the domestic fowl (chicken) is the most numerous bird in the world, and it has been suggested that the house sparrow and the European starling may be as numerous.

3. Bird Populations

A population is the total number of individuals in an area. Although the term is usually applied to a single species, it is commonly used to cover all the species in an area. Since interactions between bird species sharing a tract of habitat are close and complex, studies of birds often focus on the entire bird community as a unit. Bird communities vary both in composition and size, and population studies cover both the diversity and abundance aspects of their structure.

Studies of bird populations are required in vertebrate pest management. Control of pest species such as house sparrows, European starlings, rose-ringed parakeets, and occasionally other species requires information on densities, feeding strategies, flocking behavior, and appropriate management procedures.

The size and structure of a bird community depends upon the environmental conditions in the area, the climate and particularly the nature and richness of the local food and habitat resources. These factors change from place to place and from season to season. Bird communities typically are dynamic, changing as the environmental conditions change.

4. Population Regulation

Although they are sensitive to fluctuation in weather and other irregular and erratic variables, bird populations in stable environments rarely deviate appreciably from the local "norm" and tend to return quickly to that norm after a disturbance.

Agro-ecosystems, however, are not stable habitats in the classical sense. They are highly unstable and changing rapidly from growing season to growing season. Here bird populations may undergo striking changes in both numbers and composition of species.

Factors that control and regulate bird populations in the wild can be divided roughly into two categories: *density- independent factors* (such as weather, natural catastrophes, habitat alterations and man-induced disturbances) and *density- dependent factors* (those factors that intensify their effects when population densities are high and relaxing when densities are low). Density-dependent factors include food availability, nest site availability, territories available for use, predation, diseases and parasites. In general, density-independent factors are those that comprise the physical aspects of the environment while density-dependent factors are the biological aspects.

The population level attained and maintained by a species or a group of species is thought of as the resource level of the local environment - i.e., its carrying capacity. To meet the requirements of this system, i.e. to fully replace themselves in the next generation - breeding adults must lay more eggs than can be expected to survive as breeding adults. The margin between number of eggs laid and number of breeding adults is generally large.

It is generally accepted that a female bird will lay as many eggs as she and her mate can raise to independence under the local circumstances. This reproductive potential is in rough balance with the mortality rate of that species.

The mortality rate of young among nidifugous birds (those that leave the nest soon after hatching) is about 75 percent, which is not surprising when one considers the hazards that chicks are subjected to during the long period between hatching and fledging.

The mortality rate of young among altricial species is much lower - roughly 45 percent - because the period between hatching and fledging is spent as nestlings with greater protection.

F. Birds as Pests

A listing of damage caused by birds would include damage to crops, buildings, livestock and ornamental plants. Some have been responsible for contamination of food and other commodities stored in warehouses. In recent years rapid jet aircraft have collided with birds in flight and some have crashed with loss of human life. The solution to this problem is not fully known.

Simple or simplistic solutions to pest bird problems are often proposed. Damage control through exclusion is often advised, as for example to prevent fecal contamination to stored commodities. Sometimes this may be impossible, as for exclusion of birds from hundreds of acres of croplands.

Lethal control, direct killing of birds, has been shown to have little long-term effect. Lethal control against a species with high reproductive potential is biologically unsound because populations will breed and return to their former numbers quickly.

It is the job of vertebrate pest management specialists primarily to carry out damage control measures. When direct control measures are to be taken against a bird species, it is essential that the population of birds be considered, and the potential impact of the control measures carefully weighed.

This caution is made because there may be two very different situations in which birds cause damage. One could say that there are (1) pest birds, and (2) birds which become pests sometimes by being in the wrong place. A definition of "pest" will make this clear. Pests have these qualities:

1. A high tolerance for and adaptability to external changes. They are not highly sensitive to minor changes in weather, food supply, available nesting sites, etc. They are flexible.

2. Low requirements for living. They can survive on minimum food of rather low quality. Their diet can vary as to what is available. Their needs are simple.

3. The ability to reproduce large numbers of offspring after the population has been drastically reduced. Recovery periods of some species can be long after drastic reduction. Not so with a pest species. Drastic reduction simply makes breeding conditions better for survivors, and they reproduce quickly.

Note that not all birds fit these definitions. A non-pest bird species can create problems for humans by:

1. Disease transmission
2. Crop damage
3. Aircraft-bird strikes
4. Other incidents where a bird population may be in the wrong place and cause some damage.

Clearly "pest populations" of the first two types must be dealt with differently.

This definition of a pest species suggests that it is not easy to classify a bird as a pest or nonpest without detailed studies on the life history, biology, ecology, behavior and population dynamics. Ideally, all these studies should be brought together before bird control programs are undertaken. In practice, this is rarely done. Too often, the solution, temporary at best, is to kill the offending birds. While this approach is politically expedient, it is not biologically sound.

Greater success will come from population management methods that rely on habitat management to decrease the carrying capacity of the environment. Alteration of cropping patterns, planting dates, etc., may give some relief, but will require re-education of the public (farmers) and changes in attitudes. Often, the crux of the bird problem is a people problem. Some fault or mistake or habit of humans often causes bird damage.

PEST BIRDS OF PAKISTAN: IDENTIFICATION AND DISTRIBUTION

By Joe E. Brooks and Ejaz Ahmad

A. Introduction

Birds have become of concern to farmers and agriculturalists because some species are granivorous, feeding upon grains and seeds which are needed for food by the human population, while other species are frugivorous and feed on fruit crops which are of economic importance. These few species out of the total bird fauna are considered as "pest birds" and require some action to prevent or reduce the damage they are capable of inflicting on field crops.

The seriousness of crop damage depends upon the growth stage at which the crop is attacked by birds. If the preferred stage is the sprouting and ripening crops, then serious damage often occurs; both the period of attack will be long and many plants will be destroyed, with consequent loss of yield. If the preferred crop stage is the mature crop, then less damage is likely to occur. At harvest, most bird damage comes to a halt and the birds are then welcome to glean the waste seeds from the fields.

When the birds' breeding season comes to an end near the time that crops are ripening in the fields, then crop damage can increase. This is because bird numbers are at their annual peak at this time and the food demands of bird populations are at peak also. The energy reserves of adult birds are minimal because they have just gone through a long and energy-demanding breeding season.

Birds usually have a minimal effect on the physical characteristics of the habitat. It is mainly through their feeding and foraging habits that they come to have an impact on the agro-ecosystem, particularly on cereal grain crops. Birds must secure enough energy each day to meet their normal metabolic requirements plus any additional needs imposed by the effects of adverse climate and temperature extremes or the effects of migration, reproduction and moulting, all of which are very energy demanding. As a general rule, reproduction, moulting and migration do not overlap.

Food consumption depends on the birds' energy demands but also is modified by the composition of the diet, food preferences and availability of various food types. The dietary composition may change due to breeding, at which time the parent birds feed themselves (which may consist mainly of grains and weed and grass seeds) and also forage widely for high-protein foods (like insects) to feed the young. Food preferences also play a role; some birds prefer the sprouting crops and seedlings, while others prefer the ripening stages, particularly grains that are at the "milky" stages. Sometimes the same species attacks several growth stages, as crows do on both sprouting and ripening maize. The availability of foods may determine which crops are attacked. Some crops may be damaged more by structural damage (i.e. breaking of wheat stalks) rather than actual food consumption. Sparrows can cause as much damage by breaking stalks of ripening wheat and barley as by picking out grains from the seed heads.

It may seem surprising that few bird species, even among granivores, have become pests of cereal grains. Reasons are simple: there are few situations where granivorous birds can rely on an abundant supply of cereal seeds throughout the year. Between periods of superabundance, when the crops are ripening and until the gleanings disappear, are interposed months when the birds must rely solely on wild seeds for their survival. Unlike insect pests, birds have no non-feeding stage in their life cycle and, unlike rodents, their limited powers of reproduction prohibit a rapid increase in numbers within a single crop growing season.

If granivorous birds are generally precluded from rapid increase in population size in relation to expansion of cereal production, how can any of them become serious pests? The answer seems to lie in (1) the mobility of certain species and (2) their habit of concentrating in large numbers within fairly small parts of their overall feeding area. These local concentrations occur as a consequence of their flock-feeding habits. This flock-feeding, along with the formation of large communal roosts, leads to pest species (e.g. *Quelea, Passer, Psittacula krameri*).

Control of pest birds is necessary to minimize crop damage and to maximize crop yields. Usually a variety of techniques are needed to deter birds from feeding on crops; rarely is one method alone effective.

B. Pest Birds in Pakistan

The majority of granivorous birds tend to be gregarious and gather together in small or large flocks for foraging and feeding. Frugivorous birds also tend to occur in groups, although not in such large numbers as the grain-eating species. Some species, such as crows, are omnivorous and feed upon whatever is at hand, even on carcasses of dead animals. In Pakistan, the following species of birds could be classified as pest birds of particular importance. Their descriptions and habits are given in detail.

1. House crow (*Corvus splendens*)
2. House sparrow (*Passer domesticus*)
3. Rose-ringed parakeet (*Psittacula krameri*)
4. Baya Weaver (*Ploceus philippinus*)
5. Blue rock pigeon (*Columba livia*)
6. Collared dove (*Streptopelia decaocto*)
7. Red-vented bulbul (*Pycnonotus cafer*)
8. Rosy starling (*Sturnus roseus*)
9. Jungle crow (*Corvus macrorhynchos*)
10. Crested lark (*Galerida cristata*)

1. House Crow (*Corvus splendens*)

Description: The house crow is one of the commonest birds in Pakistan. The striking black color of its body, beak, forehead and legs is in sharp contrast to its grey neck and breast (Fig. 1). The sexes are alike in external appearance. It is a medium-sized bird, measuring about 43 cm in length. The bill is stout and powerful. It emits a short, sharp raucous call, in flight, on the ground, or while perched.

Habits: Perhaps the most familiar bird of towns and villages of Pakistan. It lives in close association with man and is almost totally dependent on mans' presence. It is, like the sparrow, bold and confiding; but also wary at the same time, ever ready to snatch a morsel of food or fly quickly off at a hint of danger. Audacious, cunning and uncannily wary. Crows have no particular food preferences and will eat almost anything: dead rats, offal, carrion, kitchen scraps and refuse, locusts, termites, fruit, grain and eggs or fledgling birds stolen from other species nests. It is highly gregarious and has communal roosts in selected trees or groves where large numbers collect every night.

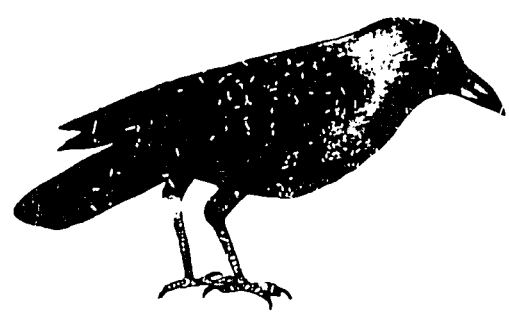


Fig. 1. House crow.

Nesting: Nesting-season is principally April to June. The nest is a bulky platform of sticks and twigs frequently intermixed with iron wire, with a cup-like depression lined with soft grasses, vegetable fibres, feathers, wool and rags. Sometimes several nests may be located in the same tree. Nests are located at least 3 meters or more up in the trees. Usually there are 4 to 5 eggs to a clutch, pale blue-green, speckled and streaked with brown. Both sexes share incubation and nest- feeding. Eggs hatch in 15 to 17 days. The nest is guarded and crows will furiously attack any intruder.

Crows invade freshly sown maize, barley, and wheat fields and dig out the emerging seedlings. The late-sown fields are usually the worst hit. Damage is generally more severe to fields nearest the crow's roosting sites. They also damage ripening crops, especially maize and groundnut. Maize cobs are attacked when the kernels are in the soft, sweet "milky" stage.

2. **House Sparrows** (*Passer domesticus*)

Description: This familiar town dweller is one of the commonest and best known birds in Pakistan. It is closely associated with man and his structures. It is a small (15 cm length) bird. The male has black streaks on brown wings, a grey crown, a black throat and an ash-grey rump, while the female has pale grey-brown back, dark brown wings and lacks the black patch on the throat (Fig. 2). Most of the population is resident in Pakistan but in the spring other subspecies may migrate through N.W.F.P, Northern Punjab and Baluchistan.

Habits: House sparrows roost communally in noisy chattering flocks in thick bushes or trees. During the day they forage in small to large flocks. They are common street birds in towns and cities. They occur in large numbers around grain mills, drying yards and around grain storage godowns, where they fly in and out of the opened structures, feeding upon waste grain mainly. They are, however, omnivorous, eating grain, insects, fruit buds, flower nectar and kitchen scraps. They sometimes collect in large flocks and damage grain crops, like wheat, rice, and millet.

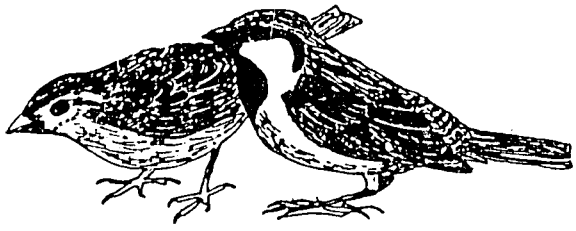


Fig. 2. House sparrows.

Nesting: They are capable of breeding and nesting almost anytime of year but the main breeding seasons are from March to July and again in September to October. They nest in holes in the walls of houses and in thick bushes and trees. The nest is made from grass, straw, wool, rags, pieces of paper and any other material at hand. The nest is a rather shapeless structure and the egg chamber is thickly lined with feathers. The clutch usually is 4 or 5 eggs of rather nondescript greenish or greyish color uniformly spotted with dark and light shades of ashy-grey and brown. Incubation period varies from 13 to 15 days and the nestlings are dependent upon their parents for food for about three weeks.

Sparrows are both beneficial and harmful from mans' viewpoint. In much of the year they feed mainly on harmful insects and weed seeds, thus rendering a service. But they need to be kept from crops during the damage periods, i.e., in rice and wheat at milk stage and from millet and rice in the fall. Reducing populations to a level where they are not causing economic crop losses probably is not feasible since they are so widespread and abundant. Instead, protection of crops at the vulnerable stages of ripening by use of repellents, scaring methods, etc. probably is a more effective means of reducing economic losses.

3. Rose-ringed Parakeet (*Psittacula krameri*)

Description: The most abundant and well-known of the parrot family in Pakistan, this parakeet is found throughout Pakistan except for purely desert or high mountain areas. It is abundant in light woodland, parks, gardens and cultivated areas. Large populations are seen in old cantonment cities in the Punjab because of the abundance of trees in these cities.

The parakeet is a medium-sized (40 cm) bird with bright green plumage (Fig. 3). The male has a distinctive black collar extending from the throat and below the cheeks where it turns into a rose-colored ring around the hind neck. Females are colored-similarly but lack the black throat collar as well as the rose-colored ring on the neck. The bill is red, short, round and strongly hooked.

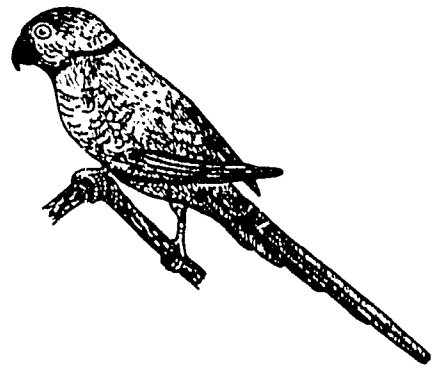


Fig. 3. Rose-ringed parakeet.

Habits: Parakeets are beautifully adapted for climbing about in trees, with two toes pointing forwards and two behind. They sometimes visit the ground, walking along with a rolling gait on their short legs. The flight is swift and direct, with rapid wing beats, the long tail streaming behind. Gives a sharp call both in flight and when on a perch. The birds are gregarious, living in flocks most of the year except for the breeding season, when they live in pairs. They are in the habit of flocking together in large numbers in the evening roost, usually a patch of trees where they roost together with flocks of crows and mynas.

The parakeet bands itself into large flocks and feeds in the countryside from dawn until mid-morning and again in mid-afternoon until dusk. It is very destructive to maize, wheat, sunflower, sorghum and other grain crops and to soft fruits, such as guava, mango, orange and loquat.

Nesting: Breeding takes place mainly from February to April. Tree holes and cavities are preferred for nest sites, although sometimes the birds themselves excavate a cavity. Holes in walls of buildings are also used. The nest consists of little more than the bare bottom of the cavity or at most a few chips of wood or debris in the bottom. Egg-laying begins in March. The clutch consists of 3 to 6 eggs, pure white, roundish ovals. Both sexes share in the incubation, with the male often gathering food and feeding the female. Incubation varies from 19 to 24 days and nearly all eggs hatch.

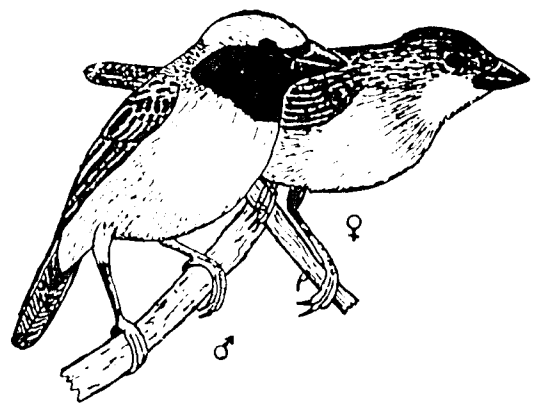


Fig. 4. Baya weaver.

4. Baya Weaver (*Ploceus philippinus*)

Description: A small (15 cm) bird, dark streaked fulvous brown above, plain whitish fulvous below, with a stout conical bill (Fig. 4). The males only acquire the yellow plumage on the crown, neck and breast and the dark mask on the throat in the breeding season.

Habits: A gregarious bird, found throughout the area in plains, grassland and cultivated areas. Not abundant. Occur in flocks in open cultivation. Resident. Gleans paddy and other grains in harvested fields. Roosts in reed beds bordering tanks. In riverain areas, inflicts considerable damage to standing wheat and other ripening crops. Also eats insects but mainly subsists on grass seeds.

Nesting: Breeds in large colonies, usually in wet areas. Makes marvelous woven grass nests hanging down from palm fronds or the branches of trees. The long hanging entrance tunnels, up which the birds have to shoot in full flight, makes the nests virtually predator-proof. Nesting season is May to September, coincident with the monsoon and paddy cultivation. The clutch consists of 2 to 4 eggs, pure white. Male alone builds the nest; female alone incubates. Each male has several nests and females at the same time.

5. **Blue Rock Pigeon** (*Columba livia*)

Description: This is a dark slaty-blue colored, stout-bodied bird with a paler greyish white rump and a broad black terminal band around its tail (Fig. 5). The sides of the neck are a glistening metallic green and purple. There are two dark bars on the wings. The bill and legs are crimson red. It is medium-sized (32-33 cm). Its flight is fast and straight.

Habits: Abundant around cities and towns in Pakistan. There are still wild populations of this pigeon, which live around ruins or cliffs, feeding in nearby fields. In the wild state it affects open country with cliffs and rocky hills. It is mainly seen as a commensal of man and is largely hybridized through interbreeding with domestic pigeon strains. This semi-feral form has become thoroughly adjusted to the din and bustle of urban life and pigeons are now well-established in most Pakistani towns. Grain warehouses, railway stations and old or disused buildings are their favorite haunts. They tend to forage in flocks and feed on cereals, millets, pulses, groundnuts, etc. They are serious pests at threshing yards just after harvest while the bundles are still lying in the fields.

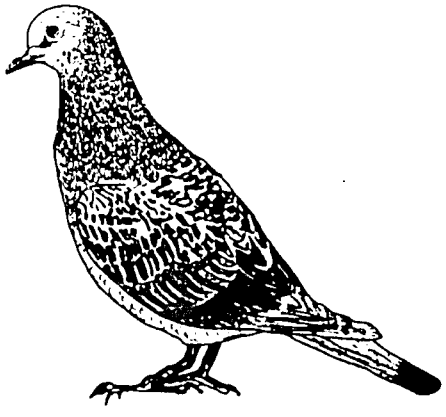


Fig. 5. Blue rock pigeon.

Nesting: The nest is a fairly flimsy platform of sticks or twigs with a slight depression in the center. It is usually placed on a ledge or in a crevice in a cliff, or on rafters and ceilings of houses, occupied or not, in any situation that affords shelter, sides of walls, etc. Breeding may occur at any time of year, although the main breeding season is March/June and September/December. Normally a clutch comprises 2 eggs, white and elliptical in shape. Both sexes share the domestic duties.

6. **Collared Dove** (*Streptopelia decaocto*)

Description: A pale pinkish-grey and brown, medium- sized (30 cm) dove with a prominent narrow black half-collar or ring on the hind-neck (Fig. 6). A rather round, plump body with a comparatively small head and a conspicuous yellow eye ring. The bill is brownish with a swollen base in which the nostrils are located. The feet are crimson red.

Habits: A very common and familiar bird. It is gregarious, gathering in flocks to feed on the stubbles, and flying up with strong, noisy wing beats. The population is resident and wide-spread throughout the Indus plains and the desert border regions. Affects open well-wooded and cultivated

country; avoids arid tracts. Becomes quite tame and confiding if unmolested, freely entering gardens and verandas of houses. Its relatively weak beak is adapted for picking seeds from the ground. It is a pest of post-harvest wheat and mustard on the threshing grounds and also is a pest of sprouting maize in Multan District.

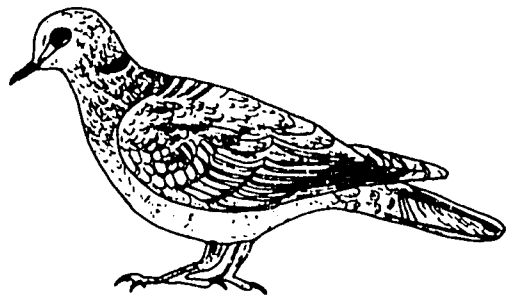


Fig. 6. Collared dove.

Nesting: The nesting season is undefined; practically all year. The nest is a flimsy structure of sticks and twigs, low down in a tree or bush; also under eaves and on cornices and beams, etc. in verandas of occupied houses. The clutch consists of 2 white eggs. Both sexes share in the domestic duties.

7. Red-vented Bulbul (*Pycnonotus cafer*)

Description: A small (20 cm), perky smoky-brown bird with partially crested black head (Fig. 7). The under tail coverts are a crimson red (hence its name), black head with a short brushy crest, while the body plumage is mostly grey-brown with a white tipped black tail. The sexes are alike.

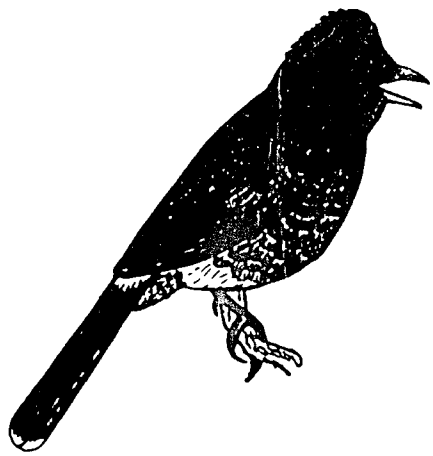


Fig. 7. Red-vented bulbul.

Habits: One of the most familiar of Pakistan birds. It abounds in gardens, towns, cultivated country, and scrub throughout the plains and hills up to about 1700 m. Bulbuls are mainly arboreal birds, and search among the twigs and foliage for beetles, grubs or fruit, sometimes imitating a fly catcher as they swoop out over the grass after an insect. The red-vented bulbul is a wary bird, and one of the first to give warning cries when a predator appears. It is a pugnacious bird. Travels in pairs or small gatherings. Common in gardens and light scrub jungle, both near and far from human habitation. Large numbers collect to feed on banyan and peepul figs and winged termite swarms. It is a serious pest of vegetables and soft fruits, particularly in Mardan and Peshawar Districts. It occurs throughout the Indian plains and sub-montane areas, being replaced in the desert and montane areas by the white-cheeked bulbul. Insects, fruits and berries, peas and flower nectar are the main dietary items.

Nesting: The nesting season is chiefly between February and May, varying with local conditions. The nest is a cup of rootlets, sometimes plastered outside with cobwebs, in a bush or tree, one to 10 m up. Two or 3 pinkish-white eggs are laid, profusely blotched with purplish-brown or claret Both sexes share parental duties.

8. Rosy Starling (*Sturnus roseus*)

Description: A rose-pink myna-like bird (23 cm) with glistening black head, neck and upper breast, wings and tail (Fig. 8). The bill is rose-colored. It has a long recumbent, pointed crest on the crown and nape, sometimes erected. Sexes alike. Young birds and adults in winter plumage (non-breeding) are duller and browner.

Habits: It is a late spring and post-monsoon migrant, arriving in huge flocks to attack millet in Sind province. Migrates in large numbers through north-west Pakistan to and from its breeding grounds in western Asia. It is highly gregarious during migration and occur mostly over Sind and southern Punjab provinces. It is omnivorous, eating ripe mulberries, as well as cereal seeds but can be of great benefit in feeding on young locusts when swarms are hatching. It begins arriving in early August, departing by mid-April. Small flocks or clouds of up to 500 birds or more keep in the vicinity of cultivation, particularly sorghum, and do considerable damage to ripening grain crops.

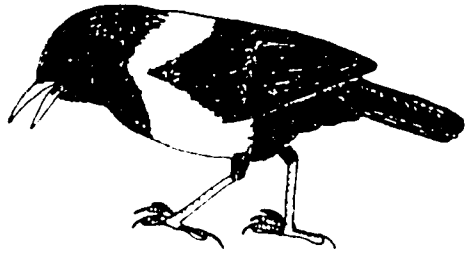


Fig. 8. Rosy starling.

Nesting: Breeds in eastern Europe and western and central U.S.S.R. on stony hillsides and amongst ruins in May and June. The breeding grounds overlap those of migratory locusts whose hoppers and other stages provide the staple food of hoards of rosy starlings and their young from the time the latter hatch out.

9. **Jungle Crow** (*Corvus macrorhynchos*)

Description: A glossy black, large (50 cm) crow with a heavy bill (Fig. 9). Sexes alike. The bill sometimes is light colored.

Habits: Chiefly a bird of the countryside but small numbers can be seen in towns and villages. Found in the montane areas of Pakistan up to the treeless slopes of the high Himalayas. Feeds on carrion and, like the house crow, is omnivorous and highly destructive to eggs and chicks of other birds. Descends to the northern plains and lowlands of Pakistan with the advent of cold weather in the mountains. Singly, in pairs or in large flocks in winter. Can be a secondary pest in groundnut and maize and will attack sprouting maize in the winter.

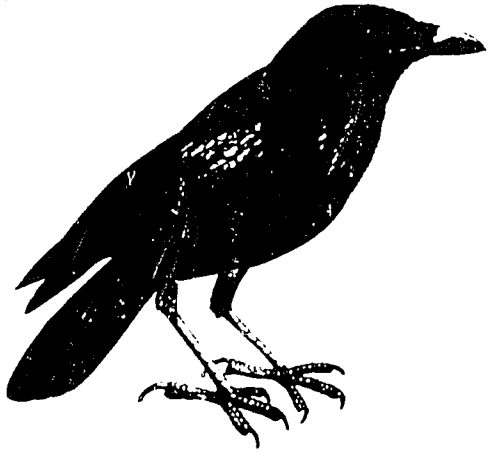


Fig. 9. Jungle crow.

Nesting: Breeding season is March to May. Nests and eggs are like the house crows. Both sexes share parental duties.

10. **Crested Lark** (*Galerida cristata*)

Description: The perky crest, pale tawny brown coloration and slightly larger size (18 cm) distinguish this bird from the other larks (Fig. 10). The sexes are alike. Its coloration helps it to blend perfectly with ploughed ground, which it frequents.

Habits: Found across northern and central Pakistan as a resident of dry or sandy open country in the plains. Occasionally flocks in winter. Affects open, sandy or stony semi-desert with scant grass ground cover. Runs about in search of food; grass seeds, small beetles and other insects. Gives a short

pleasant song during its display flight which consists of soaring a few feet above the ground on leisurely fluttering wings. Also gives the song while on the ground on a clod of dirt or from a bush top. Has been known to damage the succulent leaves of rapeseed plants and chickpeas and to dig up and open freshly sown sunflower seeds. Minor pest.

Nesting: Breeding season is March to June. The nest is a shallow cup of grass, lined with hair, feathers, etc. in open country at the base of a grass tuft or clod. The clutch consists of 3 to 4 eggs, dull yellowish white, blotched with brown and purple. Both sexes share in building the nest and tending the young. Female alone is believed to incubate the eggs.

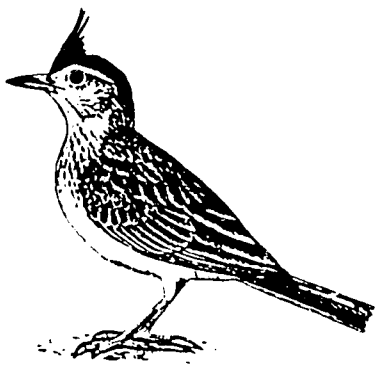


Fig. 10. Crested lark.

DAMAGE PATTERN OF PEST BIRDS AND ASSESSMENT METHODS

By Abdul Aziz Khan and Ejaz Ahmad

A. Introduction

Bird pests of crops and orchards are a chronic problem for the farmers, particularly following the introduction of high yielding cereal varieties. In Pakistan, a few species are granivorous, that is they feed upon grains and seeds which are the needs of humans, whilst others are frugivorous and feed upon fruits which are of economic importance. Thus they come into potential or direct competition with man for limited and valuable commodities. The damage pattern and assessment methods will be described here of those species which cause economic losses in crops i.e., wheat, maize, sunflower, groundnut and citrus.* Recognition of the type of bird damage, identifying the target species, together with the study of the feeding habits and foraging behaviour of different species, is very important from a point of view of control measures.

B. Damage Patterns

The techniques used by birds to obtain food are extremely variable and even a single species may use several methods to do this. Feeding patterns of major bird pests of Pakistan can be outlined and classified as follows:

1. Birds feeding by direct perching and pecking at standing crops e.g. sparrows, weavers and starlings.

2. Birds feeding by direct perching or indirectly reaching a food item from an adjacent perch. The seeds are then extracted, or whole fruiting parts are cut off by a pincering action of the bill e.g. parakeets feeding on maize, sunflower and fruit crops.

3. Birds feeding by cutting off a food, flying with it in the bill to a convenient perch and grasping it by the foot for eating, e.g. parakeets feeding on wheat ears, rape-seeds and small maize cobs.

4. Birds picking up seeds from the ground or digging out seeds and seedlings after sowing e.g. turtle doves, rock pigeons and house crows.

5. Birds directly perching and pecking at ripe fruits or vegetable leaves e.g. red-vented bulbuls and parakeets feeding on soft fruits and vegetables.

1. Parakeet Damage

Parakeet has two distinct feeding habits (Fig. 1):

a) By perching on crop heads or hanging upside down to feed gnawing on inaccessible food objects.

b) By cutting off a food object, taking it to a high tree and using the digits of its foot as a hand to grasp it for eating.

Parakeet damage to maize, sunflower and fruit crops occurs during the ripening stage. Sunflower becomes more vulnerable during the last two weeks when the seeds reach their stage of

development before the heads are completely dry. Rose-ringed parakeets have developed a flock-feeding habit particularly at early morning and late afternoon. They feed directly perching on a maize cob or sunflower head or indirectly approaching it by a hanging down manner. In the case of maize, the cob spathes are torn off and seeds extracted by a pincer-like action of the lower mandible. Characteristic signs of maize damage can be noted by the appearance of torn off spathes, extraction of seeds from cobs and the presence of scattered black cobs on the ground. A parakeet can also completely sever through the husk of a maize cob or horizontally cut the stem of a wheat, rice or rapeseed pod and carry the severed portion in its bill to a tree where it is grasped by the foot and seeds extracted. Weaver birds and house sparrows do not have sufficiently strong bills to tear open maize cob spathes but will attack and eat corn already exposed by parakeets.

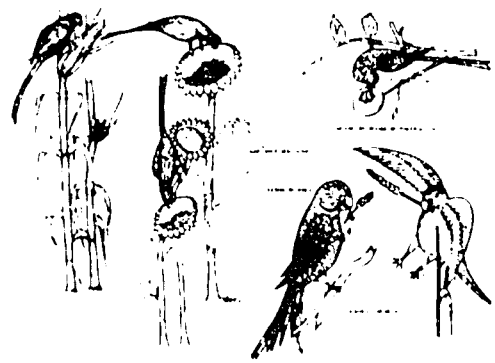


Fig. 1. Typical feeding methods and types of damage by parakeet to crops.

Sunflower seeds are also extracted from hulls in the same manner and signs of damage can be noted by the appearance of seeds being removed and sometimes the petals being eaten. Parakeets hull the sunflower seeds before eating. Scattered black hulls are found on the ground as well as on the heads and their immediate surroundings. Parakeet damage to fruit e.g. oranges can be recognized by the appearance of irregular cuts made into the orange skin by the pincer action of the mandibles while the fruit is attached to its branch and contents are eaten. Signs of the use of mandibles can be detected on the edges of the cuts. Soft fruits like pears and guava are directly consumed.

2. Bulbul Damage

Red-vented bulbuls peck at ripe soft fruits such as persimmons, and, after initial damage by parakeets, on citrus fruits. They also peck at leaves of vegetables like cabbage and cauliflowers. Collared or turtle doves and blue rock pigeons are adapted for picking up seeds and fruits from the ground or digging out seeds or seedlings after sowing. They cannot perch and peck at heads of standing grain crops, with the exception of sorghum, because of their heavy weight and weak bills. Their feeding is mainly confined to threshing grounds or around bundles of freshly harvested grain crops, as well as around the loading and unloading bays of grain stores.

3. Sparrows Damage

Sparrows damage wheat by perching on the stems just below the panicle and pulling the wheat grains loose one by one (Fig. 2). Sometimes the stems break under the weight of the birds. Sparrow damage to wheat occurs over a period of 5-7 weeks during the ripening stage depending on the variety sown and date of ripening. The crop is not attacked while the ears are showing pollen grains and feeding starts as soon as the grain develops and the milk stage is reached. It gradually decreases after the grains become hard. Damage is relatively heavy and localized around the edges of the fields and in the close vicinity of roosting trees and mud walls surrounding such fields. Damage may be particularly heavy within 50 to 100 meters of trees and fences. With the ripening of the grain, and as the crop matures, damage gradually spreads from the edges into the interior of the fields.

Sparrows feed intermittently throughout the day in scattered small flocks, comprising usually 20 to 30 birds. But feeding is intensified during the early morning and late afternoon hours, especially as the weather gets hotter, when flocks of up to 300 birds can be observed.

When the wheat is still green, sparrow damage to wheat in the field can often be recognized from a considerable distance by the relative pale yellowish appearance of the empty ears. Other grain-eating birds e.g. common weavers (Bayas), which are related to sparrows, also feed by pecking at standing cereal crops but they tend to be more localized in distribution and more gregarious in their feeding habits, with damage being rare outside the immediate riverine tracts.

Fig. 2. Typical feeding methods and types of damage by house sparrows to cereal crops.

It has been recorded that Maxi-Pak wheat variety suffers the highest damage followed by Chenab-70, while the indigenous varieties are not preferred by the sparrows. The probable reason for a more severe bird attack on Maxi-Pak and Chenab-70 as compared with the indigenous varieties is the presence of relatively loose grain coverings in the case of these two varieties.

4. Indian House Crow Damage

It has been observed that the crows damage the wheat fields either by removing seeds or seedlings. They dig out hurriedly the grains with their beaks and eat them. How they locate the seeds in the soils is worth investigation. In the case of seedlings, the crows pull them out and eat the grains. The mode of damage is interesting and skillful. Seedlings (2.5 - 7 cm) after being pulled out are thrown away and the grains then uncovered with the beak are swallowed.

Crows can be serious pests locally when their population is high and suitable roostings are available around. Also, crows damage groundnut in sandy areas where it is easy for them to pluck the pods from the soil with their beaks, digging not more than 2 to 5 cm deep. They make a small hole at one side of the shell and can easily take out the nuts without having to open all the shell and sometimes shells remain attached to the plant. Crow damage occurs throughout the field.

C. Damage Assessment Methods

Estimating bird damage to crops can be done by any of several methods depending on the time at ones disposal, the size of the area to be sampled and the number of persons available for sampling. Each method has advantages and disadvantages. Meaningful estimates of losses from birds are only possible on the basis of samples taken at random in which the damage can be quantified. Measuring the extent of damage caused by birds is a formidable task because of the wide variance obtained between fields, districts and provinces and the fact that birds rarely feed on crops in a systematic manner. Nationwide surveys are mostly done based on production and area data for each crop and usually a stratified sampling procedure is adopted to pick up the required size of sample. For most, general estimates can be obtained simply by transversing a field several times and scoring randomly selected heads as damaged or undamaged.

1. Estimating Damage to Cereals Such as Wheat or Rice

This can be done by using either visual or weighing methods. There are two methods of making bird damage estimates visually.

a) Visual Methods

One of these involves the transect counting method, in which a line through the centre or diagonally across a selected crop area is followed. A count is made every 3 to 5 paces of the number of partly or totally damaged heads in a complete plant. The other method involves throwing a wooden, square meter frame about 25 times at random into different portions of the selected field and then counting the number of damaged and undamaged heads that come within the square.

In both methods the percentage damage is calculated as:

$$\frac{\text{Damaged head}}{\text{Total No. of heads examined}} \times 100$$

The estimate can be further refined by visually scoring the percent damage to each head in general categories such as:

Category	1	(10% level)	damage	estimated	between			1- 20%
"	2	(30% ")	"	"	"	"		21- 40%
"	3	(50% ")	"	"	"	"		41- 60%
"	4	(70% ")	"	"	"	"		61- 80%
"	5	(90% ")	"	"	"	"		81-100%

b) The Zig-Zag Sampling Method

We recommend the zig-zag method for visual sampling of bird damage. It eliminates bias and gives a representative sample in the case of bird damage which tends to occur in clustered areas near edges of the crop or convenient perching trees. This involves taking samples at random points by zig-zag walking. Starting in one corner of the field and traversing 5 paces along the edge, a first sample point is taken. The second sample is taken after walking the same number of paces at right angles into the crop. Then again walking parallel to the field boundary in the original direction in order to take the third sample. Zig-zagging continues and samples are taken until the opposite field boundary is reached and then a reverse direction is followed. At each sampling point, a stick is thrust into the ground and the 5 heads (sub sample) whose tips come nearest to it are selected and percentage damage is estimated. A total of 150 heads thus counted from 30 sampling points gives a better estimate for an area of about 0.25 hectares. As indicated above this method avoids bias towards or away from the crop edges where most of the damage, if inflicted by birds, is likely to occur.

c) Weighing Method of Damage Estimation

A more accurate and elaborate method involves taking a 1/4 of a hectare plot in which the harvest is underway. Plots should be chosen from all parts of the field so as to give as wide a distribution to the damage estimate as possible. About 200 heads are randomly selected along a zig-zag route through the plot at the rate of 5 heads (ears or panicles) every 4 to 5 steps. Each head is cut off just below the first node below the panicle and immediately placed into plastic bags marked as "damaged" and "undamaged" and taken to the laboratory for weighing. From the mean weight of undamaged heads a theoretical undamaged weight for the whole sample is calculated. The difference between this weight and the actual weight of the whole sample gives an estimate of the damage level in each plot.

Example

Weight of bag containing damaged grain heads = 62 gm.
Weight of bag of undamaged grain heads = 280 gm.
Number of panicles or heads in damaged bag = 38
Number of panicles or heads in undamaged bag = 96
Weight of one undamaged panicle = 280/96 = 2.9 gm.
Theoretical weight if all the 134 panicles
had been undamaged = 134 x 2.9 = 388.6 gm.
Actual weight 62 + 280 = 342 gm.
Therefore total loss = 388.6 - 342 = 46.6 gm.
Therefore total % loss = $\frac{46.6 \times 100}{388.6}$ = 12.0%

A more suitable method for estimating damage to maize involves measuring the length of damage in each cob with reference to the total length of that cob in a large sample, (see page 156), to allow a better overall estimate of damage. Follow rest of the procedure for sampling individual fields as in the visual method for sunflower damage estimation.

2. **Damage Estimate to Fruits Such as Citrus or Mangoes**

This is a visual method whereby 20 trees are randomly selected from a one-hectare plot in each orchard. Each tree is marked and a sub-sample of 30 fruits is selected from a bunch of randomly chosen branches from the top, middle and lower parts of the same tree. Approximately 10 fruits from each of the three zones per tree are examined in the total sample. Each fruit is then scored with reference to damaged and undamaged and the percent of such damage is calculated. The product of the percentage of fruits damaged and the level of damage will give an overall estimate of damage for that particular orchard. Fruits missing or fallen from branches or otherwise damaged by fungus or insects attack can be discarded. A long bamboo stick equipped with a hooked device can be used for pulling down the higher branches, when counting fruit on bigger trees such as mangoes. In the case of citrus trees if it is possible to count all the fruit on one tree, which is not difficult when the trees are of small size, this would give a more reliable basis for sampling.

3. **Damage Estimate to Sunflower**

a) **The Visual Method**

In the randomly selected fields, heads are examined at random. From the selected field at least 10% of the rows are picked up randomly with the help of random tables and these are then marked with masking tape so that we do not lose the selected row. Then, within each row, heads are examined after walking 10 paces starting from the edge of the field, i.e. from the selected row No. 1 or head of every 20th plant is examined in the row. The extent of damage to each head is determined by a visual estimate. Damage, thus, is estimated in classes of 0, 25, 50, 75 or 100% loss of seed due to parakeets. It is then calculated as cumulative percentage for individual fields.

b) **The Template Method**

The template method uses a semi-circular clear plastic overlay template marked off in successive concentric tiers at 2 cm. intervals (Fig. 3). Each tier is further marked off into 5 cm^2 sections to provide reference marks. The template is then centered against a sunflower head and the total head diameter, the diameter of the undeveloped centre portion of the head, and the extent of damage (removed seeds) are estimated in square cm. Total percentage loss for each head can be determined by dividing total cm^2 area of bird damage by total cm^2 area of seed originally available on the head.

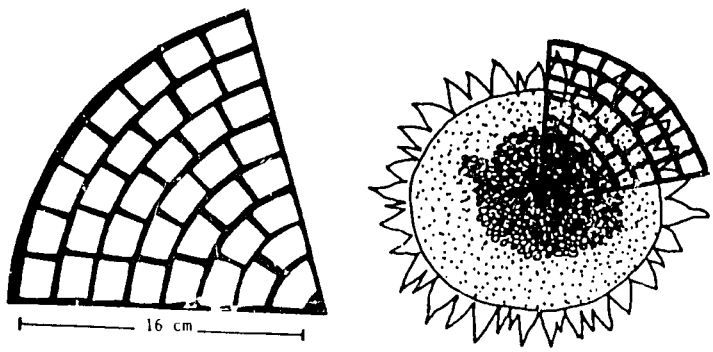


Fig. 3. Plastic template with 5 cm^2 sections and placement on sunflower head to estimate damaged area and total seed area.

TRAPPING, NETTING AND SCARING TECHNIQUES FOR BIRD CONTROL

By Iftikhar Hussain

Birds damage agricultural crops, may create health hazards, and in a variety of ways can be a nuisance. The management of bird populations or the manipulation of bird habitats to minimize such conflicts is an important aspect of wildlife management.

Traditional control methods aimed at scaring or chasing birds from the crops usually depend upon noise-making devices but are costly in human labour terms and furthermore have largely been unsuccessful and time consuming, as to be effective, they require human patrolling before and after normal working hours. They provide at best only temporary relief. We will discuss here the non-chemical methods of bird control.

A. Trapping

Pilot control trials have shown that a decoy trap based on the modified Australian crow trap (MAC), which is proposed to call the PAROTRAP, is effective in capturing live parakeets and sparrows in the field.

1. Design of Parotrap

The PAROTRAP adapted from the MAC trap measures 1.65 m long x 1.2 m wide x 2.4 m deep and has the following features (Appendix 1):

It consists of six separate pieces, together with one entrance board in which has been cut 2 longitudinal slots designed to allow parakeets to enter the trap without being able to fly out again. Bolts and nuts are used to enable traps to be easily assembled or dismantled in 10-15 minutes. The trap when in use must also be provided with 2-4 decoy birds (both sexes), a locally manufactured one-gallon poultry drinker, and enough food (both cut fresh fruits and millet seeds). Water and food, must of course, be replenished as required to sustain decoy and trapped birds. Tree branches should be placed in trap corners to provide perches. Traps should be located at the edge of ripening crops or at sites likely to produce a good catch such as observed favourite perching and roosting sites.

Four basic adaptations are essential in the design of PAROTRAP which are as follows:

a) The width of each longitudinal slot in the top entrance board should measure 4.4 cm for parakeets and 3.8 cm for house sparrows.

b) The length of each slot should be shortened to measure 15 cm less (7.5 cm on each end), a difference which creates a barrier against the side walls of the trap, so as to prevent parakeets from climbing their way out at the end of the board, adjacent to the wire mesh walls.

c) Light gauge sheets of galvanized iron are cut into four strips, 15 cm wide. Two of these strips are fixed along the inner longitudinal length of the two out-most edges of the slots so that they hang vertically inside the trap at about 45^0 angle, and the other two shorter pieces across the inner width of the entrance board. This deprives the entering parakeets from using their feet and hooked bills in climbing their way anywhere along the length of the slots. Cut rectangular pieces of welded wire should also be fixed on outside top corners of the trap for further reinforcing the ordinary chicken mesh wire corners, as we found that the birds tend to try and cut their way out of the trap from these top corners.

d) A large wooden or metal food tray (1 m x 30 cm x 5 cm), provided with fresh fruit and dry millet seeds as a bait should be placed inside the trap, by hanging it from the bottom of the entrance board at a well exposed and high position not more than 30 cm from the opening. This is in order to make the food more visible and attractive to parakeets as they have been observed to approach the tray through landing on the roof ridges looking for food. This higher placement of the food tray has proved to be more effective in attracting more birds as most of them previously were observed climbing all over the outsides of the trap walls attempting to reach the feeding site when the tray was either placed on the floor of the trap or at a lower level. House sparrows, by contrast, prefer to forage on the ground and were equally attracted by food trays placed on the floor of the cage.

3. Advantages of Parotrap

The advantage of this technique over other bird control measures are that:

a) It is a non-lethal, portable and self-operating trap which strongly attracts birds which tend to feed gregariously by the visibility of the food bait as well as the feeding behaviour and different combinations of calls uttered by the decoy birds.

b) It is economical, easy to operate and can be used both as a control method and as a continuous source for providing pet birds (in case of parakeets) and protein rich food (in case of house sparrows).

c) It can be easily manufactured by a local carpenter using own plan drawings. It can be used for a number of years if well maintained.

B. Netting

1. Mist Net: Nets may be bought in various sizes and mesh sizes. For sparrow sized birds a mesh of 1.5 cm is suitable. These nets normally have three or four shelves. Nets 20 m in length x 3 m high provide a very large catching area. Shorter nets (9 x 2 m), are also of value for use in narrow valleys and confined places. Single-shelf nets, only one meter high have a relatively small catching area but are of value in open areas where the birds are flying low among tall grasses. Nets are attached to (4 m) long poles of bamboo, wood or metal (Fig. 1). It is most convenient to carry poles of light alloy, cut into short length (1.5 m long) that can be joined as required.

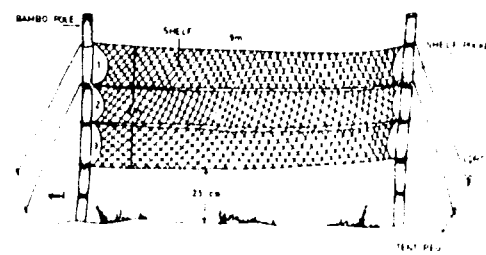


Fig. 1. Mist net setting.

Before erecting the net, a clear space for it must be found or prepared. This should be longer than the net and at least 3 m wide. In a strong wind the net can be blown far out from the centre line. The ground should be cleaned of broken branches because when the net becomes full of birds it hangs down and becomes badly entangled with any thorn branches. The poles should be placed in holes dug into the ground or pushed in if ground is soft. Poles at each end of the net should be supported by two strong cords tied to metal tent-pegs driven firmly into the ground. In a correctly erected net, the horizontal shelf-strings should be tight and the vertical strings quite loose. The bottom of the net should be 25 cm above the ground. The exact positioning can be determined by watching the net from a distance and adjusting it according to the birds behaviour. To test that the net is properly adjusted, stand a little away from it, on either side and toss a light object (i.e. a tightly knotted handkerchief) at

the net. It should fall into a pocket and hang well below the level of one of the shelf strings. If it bounces back or goes into a shallow pocket (from which a bird would escape) the vertical spacing of the shelves should be reduced by moving them up or down the poles.

After erection, the net must be watched continuously from a distance or at least visited frequently. Small birds die very quickly if left hanging out in the sun and large birds if not liberated quickly will tear the net. Other predators may attack birds on lower shelves and large animals may walk into the net. It is generally recommended to remove the net at night.

The technique for removing birds from a mist net can only be learnt by working with someone who is well experienced in the procedure. A bird can only be taken out of the net on the side on which it entered, it cannot be pushed through the netting. First the feet are cleared of the netting and held by one hand to prevent the birds from gripping the net, then the loose netting round the bird is peeled forward over the wings, body and finally over the head. Release of badly tangled birds requires much practice. Other unrequired species must be removed with great care and liberated immediately.

The net is taken down by feeding it into a cloth bag. This is done by two persons, one to keep the net off the ground while the other feeds it into the cloth bag.

2. Clap-Net: In some situations, netting by using a local made clap-net (12 x 4.5 m) equipped with a pull cord and provided with tethered decoy birds and a suitable bait can effectively reduce a local parakeet population provided that this method is being used before the onset of damage and throughout the ripening stage until harvest.

C. Scaring Devices

The use of scaring devices can be extremely effective in manipulating bird concentrations. The three keys to a successful operation are timing, organization and diversity. Useful scaring devices include broadcast alarm and distress calls, exploders and other miscellaneous auditory and visual scaring devices.

1. Exploder: The exploder produces a loud explosion at timed intervals, and has been used in a variety of bird problems (Fig. 2) To be effective, this device must be moved often, preferably every 2 or 3 days and regular maintenance is needed for proper function. To project the sound over a greater area, the exploder may be mounted on a platform or tower, changing the time interval between explosions to prevent birds from becoming accustomed to the exploder.

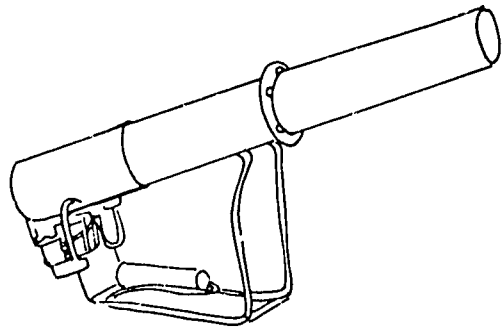


Fig. 2. Timed bird-scaring exploder.

2. Shell Crackers: These are used to move birds out of problem areas. These shells are fired from a 12-gauge shotgun, and shoot a projectile which explodes approximately 65 to 70 m away. Care should be taken not to set dry vegetation on fire.

3. Rockets: These are also used for the purpose of scaring birds. The rockets do not require a shotgun; however for better accuracy, they should be launched from a launching rod. The rocket has a much greater range than shell crackers, and the hissing sound, as it travels through the air, adds to its frightening power.

4. **Scarecrows**: The scarecrow is one of the oldest control devices, and if used properly, can be fairly effective. The larger the number used, the better. The scarecrows may be made from a variety of materials; old clothing, grain sacks stuffed with straw, or a black plastic flag hung from a tall pole. The important thing is that it moves or swings in the wind. Like the exploders, it is important that the scarecrows be moved every 2 or 3 days.

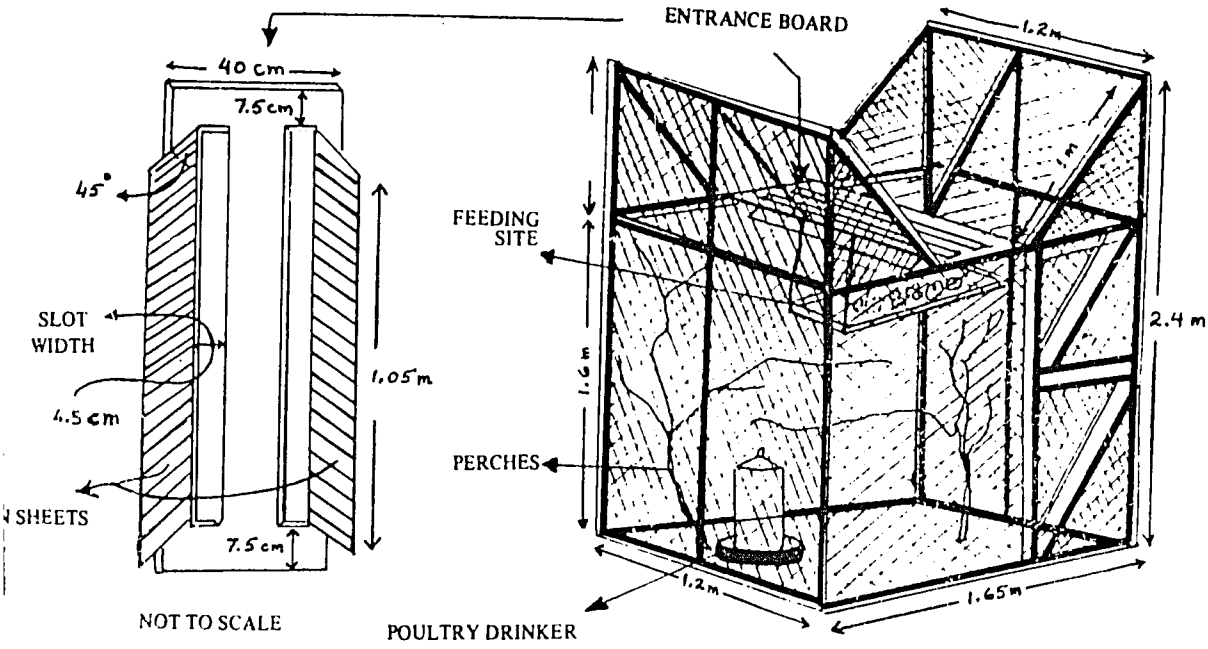
Other physical repellents involve the use of traditional scaring devices such as various rattles constructed from pots, bamboos or tin cans which can be strung across fields to combine noise with the visual effect of a human manipulating the strings.

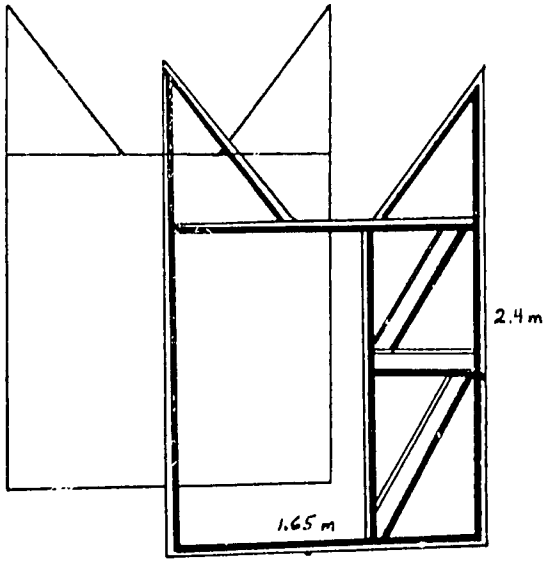
5. **Reflecting Tape**: This is a material fabricated and marketed in Japan. This tape is an elastic, transparent, synthetic resin film to which a silver metal layer is applied by vapor deposition, then coated with a colored synthetic resin. In Pakistan the local made tape is also available. This tape is used in wedding ceremonies for decoration of cars and rooms. At the eve of Eid Milad-un-Nabi (Birthday of Holy Prophet, Peace be Upon Him) this is used for decoration of mosques.

The tape reflects sunlight to produce a flashing effect and, when stretched, it pulsates and produces a loud, humming, or sometimes thunder-like noise in the wind. The tape is tied to the tallest heads of the crop or by erecting the bamboo poles about one foot above the crop heads with a 5 m interval perpendicular to the prevailing wind direction. Our experience of use of this tape at NARC on the sunflower and groundnut crops against parrots and jungle crows have produced very good results.

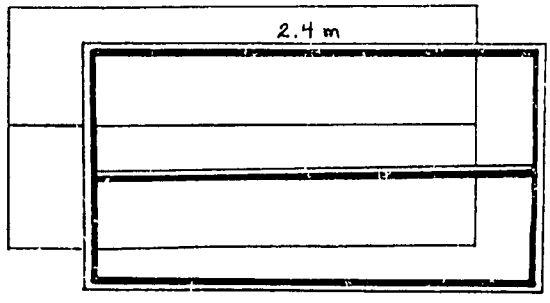
6. **Electronic Devices**: Alarm and distress calls of birds recorded on 8-track or cassette tapes are very effective in scaring many species of birds and are useful in both rural and urban situations. The calls are amplified and broadcast. Mobility of broadcast units enhances the effectiveness of such calls. However, if stationary units are used, increased volume results in greater responses. Electronically produced sounds, such as AV-alarm or other sound generators will scare birds, but usually these sounds are not as effective as amplified recorded bird calls. This should not discourage their use, however. The greater the variety and disruptiveness of sounds, the more noticeable the repellent effect will be. Any scaring devices used in the field should be removed after harvest.

DETAILS OF PAROTRAP

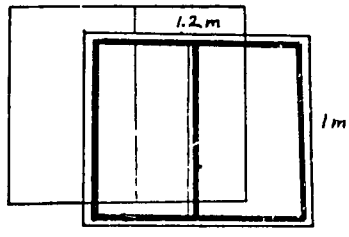




FRONT PANEL (Make 2/one with door)

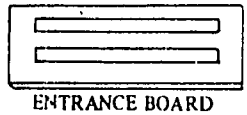


SIDE PANEL (Make 2)



TOP PANEL (Make 2)

BOLTS & NUTS
(Make 8/trap)



ENTRANCE BOARD

CHEMICALS FOR BIRD CONTROL

By Joe E. Brooks and Iftikhar Hussain

A. Lethal Control

1. Poison Baits

Starlicide (3-chloro-p-toluidine hydrochloride) is a slow-acting, highly toxic (to starlings, blackbirds, and crows) avicide, used in grain baits for lethal control of starlings, blackbirds and crows. It has been used to reduce starling damage at cattle feeding areas in the United States of America (USA) and to reduce crow and raven damages at sheep lambing areas in the Western USA.

Starlicide is highly toxic to starlings, blackbirds, crows and ravens, is generally much less toxic to other birds (such as house sparrows and hawks) and relatively non-toxic to mammals.

The toxic nature of starlicide is slow-acting and apparently painless to the birds. In starlings, the time between eating the poisoned bait and death is between 3 to 50 hours, depending on the amount ingested. It is not possible to reduce this latency period even by giving 25 times the lethal dose level. Toxic symptoms include listlessness, inactivity, and slightly increased and difficult breathing.

Death occurs without convulsions or spasms. At death, the dead birds usually have their feathers fluffed and feet tucked inside the feathers of the lower breast.

Starlings metabolize the compound completely within 2.5 hours and the metabolites are excreted completely by this time. These metabolites are non-toxic. All are excreted while the bird is still alive and there is no secondary toxicity to scavengers eating dead birds.

Starlicide is used at a 1% concentration on grain or pelletized poultry feed baits. The treated baits are generally mixed with untreated baits in the ratio of 1 part treated to 9 parts untreated before applying. Crows and ravens were killed using 200 cubes of 1.5 cm raw mutton dusted with 1 g of starlicide (75% concentrate) mixed with 5 g of powdered sugar. This gave an approximate amount of 3.75 mg of starlicide on each cubed bait. Baiting should be continued for about 6 weeks to achieve a 99% kill.

2. Contact Poisons

Typically, a bird will not fly directly to a nest, perch, or food source but will perch briefly at a convenient peripheral point to survey the situation. Control with contact chemicals take advantage of this behavior. The contact, toxic wick perch was developed to provide temporary perches.

The wicked perches are essentially hollow metal tubes with a permeable wick that contacts the perching bird's foot and permits transfer of the toxic solution to the foot surface. The chemical is absorbed through the skin, enters the bird's body and causes death some hours later.

Two insecticides have been used as contact toxicants to poison birds. These are endrin and fenthion. They are used in perches that contain wicks soaked with a solution containing one or the other of the two materials. Both are readily absorbed through the skin. Since endrin is a chlorinated hydrocarbon and fenthion is an organophosphate material, fenthion is less hazardous to humans and other non-target animals and is much less persistent in the environment. Endrin is used at a 9.4%

concentration and fenthion at 11% concentration. The artificial perches are made to take 1 oz. (30 ml) of the toxic insecticidal solution.

B. Frightening Agents and Repellents

1. Frightening Chemicals

Avitrol (also known as 4-aminopyridine) is a highly toxic bird management chemical for use as a frightening repellent in social birds that feed in flocks (such as parakeets and crows). It is usually made up as a grain bait. Treated bait is generally diluted with untreated bait so that only a few birds in a flock eat a treated bait.

Birds eating the treated baits become disoriented, give out distress calls, exhibit erratic flights, tremors and convulsions before death. Affected birds generally die. Distress usually begins in about 15 minutes and lasts 20 to 30 minutes. The affected bird's erratic behavior and distress calls frighten the other birds in the flock, causing them to leave the area.

Avitrol is used at a 3% concentration on the treated grain (cracked corn) and the treated grains are then diluted with 99 parts of untreated cracked corn. In the field, this material is broadcast at the rate of 1.1 kg/ha.

Avitrol is highly toxic, both to birds and mammals. The LD_{50} values generally are less than 10 mg/kg. All precautions used when handling a highly toxic poison should be followed; wear gloves when placing the treated baits, do not smoke or eat after handling poison baits until washing thoroughly, store poisons in a locked room or cabinet, dispose of used baits by burning or burying in the soil.

2. Repellent Chemicals

a) Methiocarb

Methiocarb (3,5-Dimethyl-4-(methylthio) phenyl methylcarbamate) is a chemical repellent used to reduce bird damage to certain fruits and to treat certain seeds (wheat, rice, maize) prior to planting. Methiocarb, when eaten by birds, apparently causes physiological distress which results in avoidance of the treated food by some bird species. Methiocarb is a carbamate insecticide that is fairly highly toxic for both birds and mammals. The LD_{50} values for rats has been reported variously as 15-35, 60, 100 and 130-135 mg/kg; for mice it is 34 mg/kg; and for pigeons and ducks is given as 13 mg/kg.

Methiocarb is applied as a seed dressing to wheat, rice and maize at 0.25% concentration to prevent bird damage to these crops as they sprout. It is applied to certain ripening fruits, such as cherries and grapes, just before harvest to reduce bird damage.

Methiocarb is poisonous if eaten, inhaled or absorbed through skin, so all precautions, such as gloves and dust mask, should be used and worn when handling the 50% or 75% concentrates.

b) Other Materials

Other chemicals have been used as bird repellent materials on seeds of cereal grains. These are fungicides, such as copper oxalate and copper oxychloride. Refined coal tar is used also to protect sprouting maize seedlings. Copper oxalate and copper oxychloride are used at 0.5 to 1.0% concentrations when used to protect wheat or maize seedlings from damage. Trimethacarb, a chemical relative of methiocarb, was shown to be an effective repellent but was not registered by the manufacturer for this use.

C. Chemosterilants

A product named Ornitrol(R) has been used as a reproductive inhibitor or chemosterilant for pigeons. It is used at a 0.1% concentration on treated maize. It causes a temporary sterility in the pigeons. The effects of one good baiting may last for six months or longer so treatment twice per year is adequate to give best results. Scatter the treated baits daily for 10 days in areas frequented by pigeons. Best results may be obtained when as many pigeons as possible are treated at the same time. Avoid unnecessary exposure to rain, since Ornitrol is water soluble. Estimate the number of pigeons to be treated, then for each 100 pigeons, scatter 7 1/2 lbs. of Ornitrol daily for 10 days.

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