PEST CONTROL: RODENTS

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Contents

1. Introduction
2. Characteristics of Rodents
3. Rodent populations
4. Types of Rodent Problems
4.1. Grain Crops
4.2. Sugarcane
4.3. Orchard and Plantation Crops
4.4. Stored Products
4.5. Forest Crops and Reforestation
4.6. Hydraulic Structures
4.7. Urban Rodent Problems
4.8. Damage to Cables, Wires, and Electronics
4.9. Rodents and Disease
4.10. Conservation of Rare Species
5. Control Methods
5.1. Integrated Pest Management
5.2. Habitat Management
5.3. Traps
5.4. Rodenticides
5.5. Biological Control
5.6. Reproductive Inhibition
5.7. Ultrasonics
5.8. Bounties and Insurance
Bibliography

Summary

Rodents are an important and ubiquitous group of mammals that occur as indigenous or introduced species throughout the world. The populations of a relatively few species that live in close association with humans sometimes cause economic damage or become threats to the health of humans or domestic animals. When rodent control efforts are contemplated, the type of problem and the objectives of these efforts should be carefully defined. Successful management of rodent problems depends upon correct identification of the rodent species involved and on obtaining information on the biology, ecology, and behavior of the species in the ecological setting where the problem occurs. Analyzing the economic costs of potential damage or assessing the risks of failure or inaction can assist in the selection of appropriate combinations of

control methods to employ. Progress in rodent control programs should be monitored regularly and success should be measured against the achievement of appropriate objectives (for example, prevention of crop damage or prevention of rodent infestations in warehouses or feed mills), not by counting the numbers of rodents killed or the amount of poison bait applied. No single method of rodent control will be predictably effective in all situations; IPM programs that apply several methods appropriate to the species and the environment where a problem occurs offer the best prospects for long-term success.

1. Introduction

Rodents are the largest, and one of the most interesting, groups of mammals. They are important components of virtually all of the earth's terrestrial ecosystems and are important herbivores that aerate the soil by burrowing activities and assist plant propagation by consuming and disseminating seeds. They are often the most important food base for many predatory mammals and birds, acting to sustain populations of these species. However, rodents also are important vectors or reservoirs of numerous diseases that infect humans, domestic animals, and other wildlife species.

They are significant economic pests that devastate crops, gardens, orchards, or landscape plantings, and damage commercial forest plantations or impede reforestation efforts. Rodents burrow through dams and irrigation structures, gnaw through communications cables and damage electronics, and consume or contaminate stored food and other commodities. Rodents sometimes prey on the eggs or young of wild birds and compete with native wildlife species for food or habitat, and thus have become important concerns in the management and recovery of threatened or endangered species, particularly in island environments.

Rodent control describes the processes that people use to alleviate rodent damage, to prevent the spread of rodent-borne diseases, to reduce problem rodent populations, or to eliminate rodent infestations. Depending on the species of rodents involved, the kinds of environments where problems occur, the nature of the problem, and the value of anticipated damage, a variety of methods is available for controlling damage or reducing rodent populations. Usually, several methods need to be used systematically to achieve lasting results. The process of selecting, applying, and evaluating the results of such combinations of control methods in relation to the ecological and economic aspects of specific damage problems is called integrated pest management (IPM) or ecologically-based pest management.

2. Characteristics of Rodents

Because of the diverse characteristics of rodent species for which rodent control may be a concern, only a very general discussion is possible. The biology, ecology, and behavior of each species or even of the same species occurring in different environments must be examined carefully to develop successful rodent control programs. What might work effectively for rodent control in a grain warehouse or urban sewer system would have little applicability or would be impractical in an Asian rice

field. However, the kinds of information needed and the principles used to develop an IPM program are the same.

There are more than 2000 recognized species of rodents (Wilson and Reeder 1993), many of which are described and pictured in Nowak (1999). A relative few of these species, perhaps less than 250 worldwide, interact sufficiently with humans to cause economic, conservation, or health concerns sufficient to warrant rodent control efforts. Biologists often rename or combine different groups of rodents to better reflect relationships as new scientific information becomes available. Whenever possible, current scientific names for rodents (Wilson and Reeder 1993) have been used when citing information from older literature.

Many readers are most familiar with "rats and mice" as the animals commonly associated with rodent control. The Norway rat (*Rattus norvegicus*), also known locally as the brown rat, wharf rat, sewer rat, or barn rat, has a nearly worldwide distribution and is almost always found living in close association with humans. The roof rat or black rat (*Rattus rattus*) and the house mouse (*Mus musculus*) are also widely distributed and, together with the Norway rat, are known as commensal rodents because of their generally close association with human habitation. Rodents range in size from the South American capybara (*Hydrochaeris hydrochaeris*), weighing more than 50 kg, to the harvest mouse (*Micromys minutus*) of Eurasia, weighing 5 to 7g. Most rodent species have thick fur, although great variations in pelage occur.

The naked mole rats (*Heterocephalus glaber*) of Africa have only bare skin, while porcupine species, such as (*Erithizon dorsatum*) of North America, have highly modified coats containing spines or quills that help provide protection from predators. Hearing, smell, taste and touch are well-developed senses in rodents, but as with many mammals, particularly the nocturnal species, their vision is relatively poor and they apparently do not distinguish colors. Rodents detect sound at frequencies substantially higher than humans; some species may use ultrasound as a means of communication (Blanchard et al. 1991).

Most rodents have long whiskers or vibrissae around their muzzles that are highly sensitive and may be used in following runways or burrows. Many rodent species are excellent climbers, using their long tails for balance. Most rodents readily swim; some, like beavers (*Castor canadensis*), nutria (*Myocastor coypus*), muskrats (*Ondatra zibethicus*), and web-footed rats (*Holochilus sciureus*), have modified appendages such as flattened tails or webbed feet that facilitate their use of freshwater aquatic habitats.

Most species of rodents are born naked and helpless, but mature rapidly. Norway rats (*Rattus norvegicus*), for example, have a gestation period of about 3 weeks, become independent of the mother at about 3 weeks after birth, and can breed for the first time within another 3 weeks. Rodents are omnivorous, exhibiting choices and preferences in their diet, but often selecting the most abundant, palatable foods available. They readily learn to reject or avoid unpalatable foods or those containing toxins, which presents a problem for the development of bait materials for effective delivery of rodenticides. The front teeth, or incisors, of rodents grow continuously and are also worn continuously by gnawing on objects or food. Because of the large space or diastema behind their

incisors, rodents can use these front teeth to investigate or nibble unfamiliar materials without actually taking them inside their mouths.

3. Rodent Populations

Because of the high reproductive capacity of rodents, their populations can grow rapidly to utilize available habitat and food. In stable environments rodents self-regulate their populations. When a population reaches the carrying capacity of an environment, reproduction declines and excess animals die (usually from disease, parasites, or predation) or emigrate to new areas. Yet rodents survive very adverse conditions—even nuclear explosions!—by living in underground burrows (Jackson 1969) and rebuilding their populations when conditions again become favorable. Habitat disruption or climatic changes that lead to increases in food and harborage sometimes give rise to population outbreaks or irruptions of some rodent species, resulting in extremely high populations that can inflict severe damage on crops (Fiedler and Fall 1994). Libay and Fall (1976) observed densities of 1 adult rat per square meter (10 000 rats per hectare!) in a breeding population of *Rattus tanezumi* in a large marsh area in the Philippines adjacent to a ricefield basin.

Rattus argentiventer in Southeast Asia, the multimammate rats (*Mastomys natalensis*) in Africa, *Mus musculus* in Australia and Hawaii, the jirds, *Meriones hurrianae* and *Meriones shawi*, in South Asia and North Africa, the Microtines (voles and lemmings) in Eurasia and North America, and cotton rats (*Sigmodon hispidus*) in southern USA and Central America all undergo periodic population irruptions. Scientists are continuing to study ways to predict such rodent outbreaks and prevent their occurrence (or at least reduce the associated damage). Surveillance of rodent populations, particularly in agricultural areas where outbreak species occur, is often an important component of rodent control. Rodent population irruptions may result in damage that is highly visible and often spectacular, devastating crop fields over wide areas. However, chronic damage and the risks of rodent-borne disease are often a greater concern from the viewpoints of economics and public health and can occur when rodent populations are relatively low—or in cases of diseases carried by rodent feces or urine, when rodents are absent. There are few places in the world where rodents are not closely associated with human enterprise. The potential for chronic losses of crops, losses and contamination of stored products, and transmission of rodent-borne diseases requires careful monitoring to determine if rodent control programs are needed or appropriate.

4. Types of Rodent Problems

The diversity of problems caused by rodents throughout the world is so great that only a few examples of some general categories of problems can be discussed. We provide a list of additional readings at the end of this chapter for readers who wish to obtain more information about rodent pest species and the different types of problems they cause in different areas of the world.

4.1. Grain Crops

Rat damage to ripening rice crops in Asia, Africa, and Latin America can be an extremely serious agricultural problem, although economic losses are often difficult to estimate because of complex patterns of growth and recovery of plants related to the developmental stage when damage occurs (Fall 1977, Fall 1980, Buckle 1994). Rats can completely consume fields of growing rice and sometimes prevent planting where crops could otherwise be grown (Wood 1994). Wheat, sorghum, maize and other grain crops are also damaged extensively by various rodent species in different parts of the world, and patterns of damage vary considerably depending on the behavior of the species involved. For example, *Bandicota bengalensis* in southern Asia cuts mature wheat and rice in large patches and establishes extensive underground food caches (Poche et al. 1982); *Rattus tanezumi* and *Rattus argentiventer* in the Philippines and other areas of Southeast Asia feed upon all stages of growing rice (Fall, 1977), while *Sigmodon hispidus* in Central America avoids wet areas in rice fields and causes damage after water is removed to dry the crop before harvest.

4.2. Sugarcane

Rodents cause extensive damage to ripening sugarcane wherever it is grown, from Asia to Africa, Latin America, the Pacific region, and Australia (Fiedler et al. 1987, Fall 1980, Tobin et al. 1990). Rats gnaw on the internodes of growing stalks, thereby killing stalks, diminishing yields, or allowing infection by bacteria or fungus, which reduces cane quality and sugar yield. Losses are difficult to quantify but can be substantial (Redhead 1980, Hampson 1984, Haque et al. 1985, Rampaud 1993, Engeman et al. 1998b). The major depredating species vary from area to area and include: *Rattus rattus, Rattus norvegicus,* and *Rattus exulans* in Hawaii*; Holochilus scuireus, Sigmodon hispidus, Oryzomys palustris, Mus musculus,* and *Rattus rattus* in North and South America*; Rattus tanezumi* in Southeast Asia*; Millardia meltada, Bandicota bengalensis,* and *Bandicota indica* on the Indian subcontinent*; Rattus losea* and *Bandicota bengalensis* in China; *Mus caroli and Apodemus agrarius* in Taiwan; *Rattus sordidus and Melomys burtoni* in Australia; and *Rattus rattus, Arvicanthis niloticus,* and *Thryonomys swinderianus* in Africa (Taylor 1984, Fiedler 1988, Prakash and Mathur 1988, Wood 1994).

4.3. Orchard and Plantation Crops

Voles (*Microtus sp.*) cause extensive damage in fruit orchards in USA and Europe (Tobin and Richmond 1993, Guedon and Combes 1990). Populations of these rodents typically irrupt periodically and, when preferred vegetation is scarce, particularly in winter, gnaw the roots and trunks of trees for the underlying phloem and cambium tissue. The resulting damage interferes with transport of nutrients between the roots and aerial portions of the tree and increases the chance of infection by root pathogens. The resulting damage kills trees, reduces fruit production, and increases the time for new plantings to come into production. Coconuts are grown commercially in many tropical areas and are subject to damage by several rodent species, particularly *Rattus rattus* and *Rattus tanezumi*. These rodents climb palms of all ages, primarily to feed on developing nuts, which then fall prematurely to the ground (Fiedler et al. 1982, Wood 1994). The proportion of nuts that drop prematurely due to rat damage can be quite high. Impacts on yield may not be proportional to the number of developing coconuts that fall to the

ground (Williams 1974, Reidinger and Libay 1981, Fiedler et al. 1982). Trees in some areas may compensate for early damage by increasing the size and weight of remaining nuts; in situations where rats feed on coconut flowers or damage very small nuts, yield losses may be underestimated by counts of fallen, maturing nuts.

Macadamia orchards in Hawaii and Australia sustain extensive damage from *Rattus rattus* (White et al. 1997, Tobin 1992). These arboreal rats gnaw through the hard shell to eat the developing kernel inside. Damaged nuts fall prematurely. Five to ten percent of developing nuts are damaged by rats in some Hawaiian orchards. However, the economic impact of this damage is not clear (Tobin et al. 1993), because some trees apparently partially compensate for this damage by producing additional nuts (Tobin et al. 1 997a). Rodents in Africa, Asia, South America, and the West Indies open ripening pods of cacao and either take whole beans or feed only on the mucilage which surrounds the beans, depending on the species of rodent (Wood 1994). Damaged pods are lost due either directly to rodent damage or indirectly to ensuing fungus infection. Damage often is greatest where cacao is grown in mixed culture with other crops such as coconut (Williams 1973, as cited in Wood 1994). Depredating species include *Rattus tiomanicus, Rattus tanezumi,* and *Callosciurus notatus in Asia,* and *Hylomyscus stella, Praomys tullbergi, Stochomys longicaudatus, Dephomys defua,* and *Praomys morio* in West Africa (Wood 1994).

Commercial oil palm plantations in Malaysia and Africa sustain damage from rodents that feed in the crowns of trees on the oil-bearing tissue of developing fruitlets. Wood (1994) reported that populations of *Rattus tiomanicus* reached between 200 and 600 rats per hectare in Malaysian orchards where no rodent control was practiced, with estimated losses averaging about 5% of the yield. *Rattus argentiventer* and *Rattus tanezumi* sometimes also become pests in Malaysian orchards (Wood 1994). In Africa, the major rodent species causing damage to oil palms include: *Dasymys incomtus, Lophuromys sikapusi, Tatera valida, Oenomys hypoxanthus, Praomys morio, Mus minutoides, Lemniscomys striatus,* and *Uranomys ruddi* (Wood 1994). Up to 80% losses have been reported in Nigeria in one year (Wood 1994).

4.4. Stored Products

Rodent consumption of stored food and grain and damage to storage structures and containers, and indirect losses caused by spillage, spoilage, or contamination that results in condemnation or rejection of shipments are important economic and public health problems worldwide (Jackson 1977, Brooks and LaVoie 1990, Conover et al. 1995). The great diversity of rodent species, storage structures, and environmental conditions and the difficulty in estimating incremental or indirect losses help mask the economic impact of the problem. Since most rodent species involved in stored product damage are nocturnal, heavy infestations may persist unnoticed without careful inspection of stores or premises (Jackson 1990). In many situations, careful grain handling procedures, indoor and outdoor sanitation, immediate disposal of spillage and garbage, frequent inspection for rodent signs, and maintenance control programs are important ways to prevent the development of more serious and difficult problems.

4.5. Forest Crops and Reforestation

Foraging by rodents can be a major impediment to reforestation efforts around the world. Direct predation on seeds by deer mice (*Peromyscus sp*.) and house mice (*Mus musculus*) in USA (Nolte and Barnett 2000) can preclude or reduce the success of direct seeding efforts. Clipping and girdling of the roots and stems of young seedlings by a wide variety of rodents is a major source of tree mortality. Pest species include: squirrels (*Sciurus sp.* and *Tamasciurus sp.*) strip bark from trees in Europe and North America (Gill 1992); voles (*Microtus sp*., *Clethrionomys sp*.) in the United States, Europe, and Asia (Myllymaki 1977, Pigott 1985, Maguire 1989); deer mice (*Peromyscus sp*.) in the United States (Maguire 1989); porcupines (*Hystrix indica*) in Asia (Khan et al. 2000) and (*Erethizon dorsatum*) USA (Wagner and Nolte 2000); pocket gophers (*Thomomys sp.*) in USA (Crouch 1986, Engeman et al. 1998a); and mountain beavers (*Aplodontia rufa*) in the Pacific Northwest (Wagner and Nolte 2000). In western USA pocket gophers (*Thomomys sp.*) damage or destroy hundreds of thousands of acres of forestland each year, severing stems and girdling roots and stems of more conifers than all other wild mammals (Crouch, 1986). Even when rodent control programs are in place, pocket gophers may quickly re-invade cleared areas and re-occupy vacant burrow systems (Engeman and Campbell 1999). Beavers (*Castor canadensis*) in North America, particularly in southeastern USA, also cause considerable damage to trees and forests as well as to landscape plantings, both directly by their feeding and dam-building activities, and indirectly by flooding caused by blocking streams and drainage structures with dams (Conover et al. 1995). Nolte and Otto (1996) have compiled analysis of tree damage by rodents and other wildlife species that provides current sources of management materials as well as a guide to identification of damage.

4.6. Hydraulic Structures

Although little has been published, a number of burrowing rodent species cause damage, water loss, and the attendant risks of flooding, by excavating earthen dams, irrigation canals, or flood control structures. Notable species involved are beavers (*Castor canadensis*), muskrats (*Ondatra zibethicus*), gophers (Geomyidae), and ground squirrels (*Spermophilus sp*.) in North America; *Bandicota bengalensis* in southern Asia; and nutria (*Myocastor coypus*) in North and South America. A variety of other burrowing species cause problems on a localized basis. Determining the cause of breaks in hydraulic structures is often difficult because animal activity is impossible to assess if the evidence has washed away. Failure to control rodent infestations, however, is potentially threatening to human life and may result in legal actions and repairs ranging to millions of dollars (Hegdal and Harbour 1991). High beaver (*Castor canadensis*) populations in many areas are now a cause of considerable concern for both forest managers and for those responsible for flood prevention and control. These large rodents move to flowing water and cut surrounding trees by gnawing around the circumference of their bases. Trees are used for dam building, lodge construction, and food. Beavers also excavate dens in the banks of reservoirs, streams, or canals, resulting in water loss and even structural failure. Beaver dams that block culverts, ditches, streams, or spillways can result in extensive flooding and damage to bridges, roads, and other structures, as well as flooding and death of trees in commercial plantations or

reforestation and riparian areas (Hegdal and Harbour 1991, Conover et al. 1995, Fall and Jackson 1998).

4.7. Urban Rodent Problems

In most of the world's cities and towns, one or more of the cosmopolitan commensal rodents (*Rattus rattus, Rattus norvegicus,* or *Mus musculus*) live with people in homes, business establishments, markets, yards, and sewers. A variety of other species occur in parts of their ranges as commensal rodents in urban areas, notably, *Rattus exulans* and *Rattus tanezumi* in Southeast Asia, *Bandicota bengalensis* in southern Asia, and *Mastomys natalensis* in parts of Africa (Lund 1994). In close association with people in dense settlements, rodents cause a variety of problems, including loss and contamination of foodstuffs, destruction of property, rat bites, gnawed electrical wiring resulting in fires, and transmission of diseases, notably salmonellosis, but a variety of others in various parts of the world.

Because of their relative prominence, rodent infestations in urban areas generally attract political attention and become the frequent subject of periodic, large-scale control efforts. Davis (1972) contended, based on his research in Baltimore in the late 1940s (Davis 1953), that enough was known about rodent population principles to control urban rodent infestations and other rodent problems. His research demonstrated that outdoor rodent populations in cities could be managed by removal of the food and habitat on which Norway rat (*Rattus norvegicus*) populations depended. Fifty years later, Fall and Jackson (1998) saw the failure of this approach related to the difficulty in maintaining the diligence of urban residents and the inconsistent support of the public and private sectors. Colvin and Jackson (1999) maintain urban rodent control must focus on strategic, comprehensive approaches that incorporate multiple tactics and partnerships among government agencies, community groups, and pest control companies. Clearly, large-scale rodent control efforts in urban areas, if properly planned and managed using IPM approaches, can be quite effective (Colvin et al. 1990).

4.8. Damage to Cables, Wires, and Electronics

Various species of rodents gnaw on above- and under-ground communications and power cables, resulting in service interruptions, fires, and other safety concerns (Shumake et al. 1999, 2000; Cogelia et al. 1976). Seismic cables laid on the ground surface for geologic mapping are often damaged by rodents and other wildlife species. About 18% of telephone and 26% of electric manholes inspected in downtown Boston had evidence of rat (Rattus norvegicus) activity (Colvin et al. 1998). Ramey and McCann (1997) reviewed research conducted in USA since the 1940s to develop cables resistant to damage by rodents, mostly pocket gophers (*Thomomys sp.* and *Geomys sp.*). Much of this research evaluated either the susceptibility of various types of cable to gnawing (McCann 1995, Shumake et al. 1999) or the effectiveness of repellents for deterring gnawing (Shumake et al. 1999, 2000). Rodents living in attics, walls, and basements commonly gnaw electrical wiring, sometimes causing fires (Jackson 1990). Mice, in particular, may readily gain access to sensitive electronic equipment, damaging wiring and circuit boards.

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