Title
Rodent Burrow Systems in North America: Problems Posed and Potential Solutions*

Journal
Proceedings of the Vertebrate Pest Conference, 25(25)

ISSN
0507-6773

Authors
Witmer, Gary W.
Moulton, Rachael S.
Swartz, Jenna L.

Publication Date
2012

DOI
10.5070/V425110499

Rodent Burrow Systems in North America: Problems Posed and Potential Solutions

Gary W. Witmer, **Rachael S. Moulton**, and **Jenna L. Swartz**
USDA APHIS Wildlife Services, National Wildlife Research Center, Fort Collins, Colorado

Abstract: Many rodent species are effective burrowers. In North America, these include species of ground squirrels, prairie dogs, marmots, and pocket gophers. The burrow systems of other species of rodents such as voles and mice are less elaborate and pose less potential for direct damage. Burrowing abilities, coupled with other characteristics (e.g., prolific, adaptable, ever-growing incisors for gnawing), can result in many types and amounts of impacts to human resources and ecosystems. Damage occurs to levees, roadbeds, buried pipes and cables, intrusion to sensitive areas (such as military sites, capped hazardous waste burial sites), vegetation effects, effects on water infiltration/runoff, and soil erosion. We describe burrow systems of select rodent species of North America and then put them in the context of potential impacts and damage reduction methods. Population reduction with rodenticides and traps are common methods of damage reduction. Non-lethal approaches such as barriers are another method of damage reduction, but these pose many challenges such as effectiveness, durability, and cost. Additional research is needed to better understand rodent burrow systems, impacts of burrow systems, and to improve effectiveness of damage reduction methods. We propose investigations of physical barriers that are effective and economical, and note that a thorough understanding of rodent burrow systems and activities is a prerequisite to the development of effective barriers.

Key Words: burrow, burrow systems, ecology, fossorial, ground squirrels, pocket gophers, prairie dogs, rodents, rodent management, subterranean, voles, wildlife damage

Proc. 25th Vertebr. Pest Conf. (R. M. Timm, Ed.)
Published at Univ. of Calif., Davis. 2012. Pp. 208-212.

INTRODUCTION

There are over 400 species of rodents in North America (Hall 1981). They are found in all eco-regions, from high arctic tundra to forests, prairies, and arid deserts. They inhabit subterranean, terrestrial, arboreal, and aquatic habitats. Most of these species do not cause significant problems for humans. However, many rodents have adapted to and taken advantage of human environments, and are considered pests in urban, agriculture, and forestry settings. Many of these rodent species excavate burrow systems that are used for various purposes. Other species do not build burrow systems, but will use naturally occurring ones or ones built by other species. Burrows can be complex or simple. Rodent burrow systems can result in various types of impacts to human activities or in damage to human resources and natural resources. In this review, we consider the main species of burrowing rodents in North America, especially species causing substantial damage to human and natural resources, the characteristics and values of their burrows, the types of impacts, and potential management options to reduce damage.

BURROWING RODENTS

Many species of rodents in North America are burrowers, however; there are species that don't burrow or only burrow to a small extent (see rodent chapters in Vander Wall 1990 and Feldhamer et al. 2003). Arboreal rodent species such as tree squirrels (*Sciurus* spp.) and porcupines (*Erethizon dorsatum*), along with some terrestrial species such as wood rats (*Neotoma* spp.) do not burrow or only burrow to a minor extent. For shelter and nesting, many species prefer natural openings, logs, debris or rock piles, trees, or other structures including those made by humans. Additionally, many rodent species will readily use burrows created by other animals. On the other hand, many species create their own burrow systems. These species include ground squirrels (*Spermophilus* spp.), chipmunks (*Eutamias* spp. and *Tamias striatus*), prairie dogs (*Cynomys* spp.), marmots (*Marmota* spp.), mountain beaver (*Aplodontia rufa*), pocket gophers (*Geomys* spp., *Thomomys* spp., and *Pappogeomys* spp.), kangaroo rats (*Dipodomys* spp.), voles (*Microtus* spp.), and mice (*Peromyscus* spp. and many other genera). A number of introduced rodent species also create burrows, including rats (*Rattus* spp.), house mice (*Mus musculus*), and nutria (*Myocaster coypus*) (Fall et al. 2011). Some species such as pocket gophers are considered to be subterranean because they spend most of their lives underground. Most burrowing rodents, however, are considered to be fossorial because they spend substantial amounts of time above ground for foraging and other activities.

Burrow systems vary greatly among rodent species and even within a species, depending on soil type, compaction, and depth; water table levels; aspect and slope; vegetation type and density; latitude, etc. (e.g., Rhodes and Richmond 1985, Laundré and Reynolds 1993, Busch et al. 2000). Some North American rodent species that create very elaborate burrow systems include ground squirrels, pocket gophers, kangaroo rats, marmots, and some chipmunk species. Perhaps the most elaborate burrow systems are those constructed by pocket gophers (Nowak 1999, Baker et al. 2003, Kern 2009). Elaborate systems can involve numerous openings into the burrow system, many branches and side tunnels, and numerous chambers for nesting, food storage, and fecal material storage. Portions of the burrow system must be deep enough to moderate the microclimate during freezing or extremely hot weather periods. Not all tunnels of the burrow system are being used at all times; some may be plugged with soil. Some rodent species, such as pocket gophers, are believed to patrol their entire burrow system fairly regularly, perhaps for defense purposes but also to make repairs. In some cases, there are lateral tunnels and downward tunnels that dead end deep underground; these are thought to be a defense against burrow flooding (e.g., Foster 1924). Additionally, mounds above ground around the burrow openings serve several functions: a perch from which to watch for predators, an aid in burrow ventilation, and prevention of burrow flooding during heavy rain or flood events. Finally, most burrow systems are open systems in that the burrow is not plugged on a regular basis except occasionally during periods of very cold or hot weather (usually involving a period of winter hibernation or summer estivation) (Marsh 1994). The exception in North America is the burrow system of pocket gophers, which are kept closed at all times except when the animal is briefly out on the surface to collect food (generally at night) or excavating a new tunnel.

Some rodent species, such as mice and voles, create rather simple burrow systems. Simple burrow systems often involve a linear tunnel ending at the nest site. Nonetheless, rodents that don't burrow or burrow very little may cache food underground independent of a burrow system (Vander Wall 1990).

Some examples of burrow characteristics of some of the proficient burrowing rodent species in North America include:

- Depth can be as great as 7 m (marmots)
- Length can be as great as 160 m (southeastern pocket gopher)
- Diameter can be as great as 22.5 cm (white-tailed prairie dog)
- Opening diameter can be as great as 30 cm (black-tailed prairie dog and woodchuck)
- Number of openings per unit area can be as great as 250 per ha (black-tailed prairie dog)
- Complexity can be great: Southeastern pocket gopher burrows have separate shallow and deep tunnels that run parallel to the surface and are connected by a spiraling shaft; chambers off the shallow tunnels are for resting and feeding, whereas the 1-5 chambers radiating off the deep tunnel are for nesting and food and fecal storage.

VALUES AND COSTS OF BURROWS

Burrows provide many advantages to rodents, but burrows also have some costs and disadvantages (Begall et al. 2007). Some of the advantages of burrow systems include protection from inclement weather, protection from terrestrial and aerial predators, a favorable and more stable microclimate, a place to store food, a place to give birth and rear young, a place for hibernation or estivation during seasonal extremes and low food availability, and also a place to allow rodents to take better advantage of underground food resources such as roots and tubers (Meadows 1991). It has also been noted that ecosystems may benefit from rodent burrow systems because of increased soil mixing; increased fertility of soils from fecal material, urine, and buried plant material; increased aeration of soils; increased microbial activity,; and improved plant regeneration from buried seeds or exposed soils as a seed bed (Meadows 1991, Laundré and Reynolds 1993, Guo 1996, Cameron 2000, Simkin et al. 2004, Reichman 2007). In many situations, rodent burrows also provide a living place for numerous other species of animals, both vertebrates and invertebrates (Cameron 2000, Hoogland 2006).

Conversely, burrows require considerable energy to construct, can become flooded, restrict the sensory cues that animals receive, and may create a microclimate characterized by high humidity, low gas ventilation, low oxygen levels, and high carbon dioxide levels (e.g., Bufferstein 2000, Burda et al. 2007).

Because burrow systems provide many advantages, but incur high energetic costs, vacated burrow systems are usually taken over very soon by other species or re-invaded by members of the same species. Re-invasion rates of >80% in a relatively short period of time have been reported by various researchers (Witmer et al. 1996, Berentsen and Salmon 2001, Van Horne 2007).

SOCIAL SYSTEMS AND BURROWS

Group living and the social systems developed and maintained in rodent populations are thought to be under the selective pressures of protection from predation, collection and storage of food, and localization and protection of a resource such as breeding and resting sites (Alexander 1974, Lacy and Sherman 2007). Patchy habitats, limited resources, and a short growing season may also encourage sociality in rodents (Hare and Murie 2007). Additionally, there is considerable energy conservation by groups huddling and nesting underground (Merritt 2010). King (1984) proposed that the sociality of ground squirrels is proportional to the value of their burrows. But it should be noted that social systems vary widely across rodent species and even across those species that create and maintain elaborate burrow systems. For example, prairie dogs (Hoogland 1995) and ground squirrels (Murie and Michener 1984) tend to be very social whereas pocket gophers are more solitary, with multiple animals in a burrow system only during the breeding season or when the female is raising young (Case and Jasch 1994, Witmer and Engeman 2007). Additionally, Mankin and Getz (1994) noted that the complexity of prairie vole burrows can vary, with more complex systems built and maintained by large social groups than the burrows of male-female pairs. Some species such as deer mice and voles aren't very social, but will huddle together to conserve energy, especially during winter months (Merritt 2010). Marmots hibernate in groups in a common burrow called a hibernaculum (Merritt 2010).

DAMAGE BY BURROWING RODENTS

While burrows provide benefits to the burrowing rodent species, other animals, and to ecosystems, they can also result in various types of damage to human structures and resources. When burrow systems occur in agricultural fields, forest lands, or rangelands, there will be resultant losses to crop production, forest regeneration, and range plant productivity (Black 1992, Hygnstrom et al. 1994, Witmer and Singleton 2010). The amount of losses depends on many factors (rodent species, time of year, surrounding land uses and habitats), but is generally related to the density of the rodent population (Witmer and Proulx 2010). These damages will occur regardless of the type of burrow system; however, the presence of the burrow system may allow rodents to be active throughout the winter and inflict much damage during that time of year (e.g., voles, Witmer et al. 2009; pocket gophers, Witmer and Engeman 2007). Burrows and burrow openings can also result in damage to farm equipment and injury to humans and livestock. Hoogland (2006) noted, however, that injuries to humans and livestock is not well documented and may be exaggerated.

The burrows created by rodents can directly impact hydraulic structures such as dams, levees, canals, and irrigation ditches (Hegdal and Harbour 1991). The burrowing can cause a weakening or failure of these structures resulting in erosion, flooding, loss of water resources, and damage to property and structures. When rodents burrow under buildings, roadbeds, or airport runways, they can cause structural damage. In addition to good digging abilities, many rodent species have very good gnawing abilities, in large part because of their ever-growing and sharp incisors (Witmer 2007). This can result in damage to buried fiber-optic cables, electric wires, and irrigation pipes. Archeological sites and burial sites can also be disrupted, and hazardous waste burial vaults can be breached.

METHODS TO REDUCE DAMAGE AND POTENTIAL NEW SOLUTIONS

Damage reduction methods for rodents generally involve lethal approaches to reduce densities using rodenticides, traps and snares, burrow fumigation, shooting, and burrow exploder devices (Hygnstrom et al. 1994, Witmer 2007, Witmer and Eisemann 2007, Shadel 2008). These methods and their use (location, time of year, restrictions, etc.) are regulated by a number of state and federal agencies, and this varies by state, county, and municipality (e.g., Hygnstrom et al. 1994). Other methods include flooding of orchards and field crops, and physical disruption of burrows (Marsh 1994). Non-lethal approaches exist (barriers, repellents, frightening devices, enhanced predation, etc.) but, in general, are not very effective (Marsh et al. 1990, Timm 2003, Witmer 2007). In general, an Integrated Pest Management (IPM) approach, using a combination of methods provides for the best long-term solution (Witmer 2007, Witmer and Singleton 2010).

A thorough understanding of rodent biology, ecology, and their burrow systems is necessary if control measures such as traps, toxicants, or barriers are to be applied effectively. Many factors can affect the effectiveness of a management technique. What works in one location may not work in another location; what works for one rodent species may not work for another species; and what works in one season may not work in other seasons. This is why having a variety of "tools" in the IPM toolbox is so important.

Examples of advantages and disadvantages of various methods for controlling rodent populations and damage are presented in the rodent chapters of the book by Hygnstrom et al. (1994). They also caution on some of the things that can reduce the effectiveness of a particular control method. For example, after consuming sub-lethal dose of an acute toxicant, the rodent may become ill quickly enough that it will associate illness with that rodenticide bait. In that case, it becomes "bait shy" and won't consume the bait in the future. Some rodent populations develop a genetic or physiological resistance to anticoagulant rodenticides. Burrow fumigants may be ineffective when soils are porous and dry. Rodents may enter periods of dormancy during hot, dry summer weather or during winter, hence control methods during those periods will be ineffective. Additionally, rodents may switch feeding preferences over the course of a year. For example, many rodents feed on succulent, green forage in the spring and early summer, but may switch to feeding almost entirely on seeds later in the year. That can affect the acceptance of a particular bait formulation.

More research is needed to improve non-lethal approaches and to reduce the non-target animal hazards associated with lethal approaches. One such research area is fertility control in rodents (e.g., Nash et al. 2007). We also need more rigorous economic analysis of the costs and benefits of burrowing rodent damage and damage reduction methods (e.g., Gebhardt et al. 2011). A better understanding of rodent burrow systems in North America would provide a better basis for developing effective control methods for reduction of damage caused by burrowing rodents.

LITERATURE CITED

Alexander, R. 1974. The evolution of social behavior. Ann. Rev. Ecol. Syst. 5:325-383.

Baker, R., R. Bradley, and L. McAliley. 2003. Pocket gophers. Pp. 276-287 *in*: G. Feldhamer, B. Thompson, and J. Chapman (Eds.), Wild Mammals of North America: Biology, Management, and Conservation. The Johns Hopkins University Press, Baltimore, MD.

Begall, S., H. Burda, and C. Schleich (Editors). 2007. Subterranean Rodents: News from Underground. Springer-Verlag, Berlin, Germany. 398 pp.

Berentsen, A. R., and T. P. Salmon. 2001. The structure of California ground squirrel burrows: Control implications. Trans. West. Sect. The Wildl. Soc. 37:66-70.

Black, H. (Editor). 1992. Silvicultural Approaches to Animal Damage Management in Pacific Northwest Forests. General Technical Report PNW-GTR-287. U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station, Portland, OR. 422 pp.

Bufferstein, B. R. 2000. Ecophysiological responses of subterranean rodents. Pp. 62-110 *in*: E. A. Lacey, J. L. Patton, and G. N. Cameron (Eds), Life Underground: The Biology of Subterranean Rodents. University of Chicago Press, Chicago, IL.

Burda, H., R. Sumbera, and S. Begall. 2007. Microclimate in burrows of subterranean rodents–a review. Pp. 21-33 *in*: S. Begall, H. Burda, and C. Schleich (Eds.), Subterranean Rodents: News from Underground. Springer-Verlag, Berlin, Germany.

Busch, C., C. Antinuchi, J. del Valle, M. Kittlein, A. Malizia, A. Vassallo, and R. Zenuto. 2000. Population ecology of subterranean rodents. Pp. 183-226 *in*: E. A. Lacey, J. L. Patton, and G. N. Cameron (Eds.), Life Underground: The Biology of Subterranean Rodents. University of Chicago Press, Chicago, IL.

Cameron, G. 2000. Community ecology of subterranean rodents. Pp. 227-256 *in*: E. A. Lacey, J. L. Patton, and G. N. Cameron (Eds.), Life Underground: The Biology of Subterranean Rodents. University of Chicago Press, Chicago, IL.

Case, R., M., and B. A. Jasch. 1994. Pocket gophers. Pp. B17-B29 *in*: S. Hygnstrom, R. Timm, and G. Larson (Eds.), Prevention and Control of Wildlife Damage. University of Nebraska Cooperative Extension Service, Lincoln, NE.

Fall, M. W., M. L. Avery, T. A. Campbell, P. J. Egan, R. M. Engeman, D. Pimentel, W. C. Pitt, S. A. Shwiff, and G. W. Witmer. 2011. Rodents and other vertebrate invaders in the United States. Pp. 381-410 *in*: D. Pimentel (Ed.), Biological Invasions, 2nd Ed. CRC Press, Boca Raton, FL.

Feldhamer, G. A., B. C. Thompson, and J. A. Chapman (Editors). 2003. Wild Mammals of North America: Biology, Management, and Conservation. The Johns Hopkins University Press, Baltimore, MD. 1216 pp.

Foster, B. E. 1924. Provision of prairie-dog to escape drowning when town is submerged. J. Mammal. 5:266-268.

Gebhardt, K., A. M. Anderson, K. N. Kirkpatrick, and S. A. Shwiff. 2011. A review and synthesis of bird and rodent damage estimates to select California crops. Crop Protect. 30:1109-1116.

Guo, Q. 1996. Effects of bannertail kangaroo rat mounds on small-scale plant community structure. Oecologia 106:247-256.

Hall, E. R. 1981. The Mammals of North America, 2nd Ed. John Wiley & Sons, New York, NY. 1271 pp.

Hare, J., and J. Murie. 2007. Ecology, kinship, and ground squirrel sociality: Insights from comparative analyses. Pp. 345-355 *in*: J. Wolff and P. Sherman (Eds.), Rodent Societies: An Evolutionary Perspective. University of Chicago Press, Chicago, IL.

Hegdal, P., and A. Harbour. 1991. Prevention and Control of Animal Damage to Hydraulic Structures. USDI, Bureau of Reclamation, and U.S.D.A. APHIS. 77 pp.

Hoogland, J. 1995. The Black-tailed Prairie Dog: Social Life of a Burrowing Mammal. University of Chicago Press, Chicago, IL. 562 pp.

Hoogland, J. 2006. Conservation of the Black-tailed Prairie Dog. Island Press, Washington, D.C. 342 pp.

Hygnstrom, S. E., R. M. Timm, and G. E. Larson (Editors). 1994. Prevention and Control of Wildlife Damage. University of Nebraska, Cooperative Extension Service, Lincoln, NE.

Kern, Jr., W. H. 2009. Southeastern Pocket Gopher. Publication #WEC67. IFAS Extension, University of Florida, Gainesville, FL. 4 pp.

King, J. 1984. Historical ventilations on a prairie dog town. Pp. 447-456 *in*: J. Murie and G. Michener (Eds.), The Biology of Ground-dwelling Squirrels. University of Nebraska Press, Lincoln, NE.

Lacy, E., and P. Sherman. 2007. The ecology of sociality in rodents. Pp. 243-254 *in*: J. Wolff and P. Sherman (Eds.), Rodent Societies: An Evolutionary Perspective. University of Chicago Press, Chicago, IL.

Laundré, J. W., and T. D. Reynolds. 1993. Effects of soil structure on burrow characteristics of five small mammal species. Gt. Basin Nat. 53(4):358-366.

Mankin, P. C., and L. L. Getz. 1994. Burrow morphology as related to social organization of *Microtus ochrogaster*. J. Mammal. 75(2):492-499.

Marsh, R. E. 1994. Current (1994) ground squirrel control practices in California. Proc. Vertebr. Pest Conf. 16:61-65.

Marsh, R. E., A. E. Koehler, and T. P. Salmon. 1990. Exclusionary methods and materials to protect plants from pest mammals–a review. Proc. Vertebr. Pest Conf. 14:174-180.

Meadows, A. 1991. Burrows and burrowing animals: An overview. Symp. Zool. Soc. Lond. 63:1-13.

Merritt, J. F. 2010. The Biology of Small Mammals. The Johns Hopkins University Press, Baltimore, MD. 336 pp.

Murie, J. O., and G. R. Michener (Editors). 1984. The Biology of Ground-Dwelling Squirrels. University of Nebraska Press, Lincoln, NE. 459 pp.

Nash, P., C. A. Furcolow, K. S. Bynum, C. A. Yoder, L. A. Miller, and J. J. Johnston. 2007. 20,25-Diazacholesterol as an oral contraceptive for black-tailed prairie dog population management. Human-Wildl. Conflicts 1(1):60-67.

Nowak, R. 1999. Walker's Mammals of the World, 6th Ed. The Johns Hopkins University Press, Baltimore, MD. 2015 pp.

Reichman, O. J. 2007. The influence of pocket gophers on the biotic and abiotic environment. Pp. 271-286 *in*: S. Begall, H. Burda, and C. E. Schleich (Eds.), Subterranean Rodents: News from Underground. Springer-Verlag, Berlin, Germany.

Rhodes, D. H., and M. E. Richmond. 1985. Influence of soil texture, moisture and temperature on nest-site selection and burrowing by the pine vole, *Microtus pinetorum*. Am. Midl. Nat. 113(1):102-108.

Shadel, R. A. 2008. Efficacy of concussion blast equipment for the elimination of groundhogs in burrows. Proc. Vertebr. Pest Conf. 23:53-55.

Simkin, S. M., W. K. Michener, and R. Wyatt. 2004. Mound microclimate, nutrients and seedling survival. Am. Midl. Nat. 152:12-24.

Timm, R. M. 2003. Devices for vertebrate pest control: Are they of value? Proc. Wildl. Damage Manage. Conf. 10:152-161.

Van Horne, B. 2007. Conservation of ground squirrels. Pp. 463-471 *in*: J. Wolff and P. Sherman (Eds.), Rodent Societies: An Evolutionary Perspective. University of Chicago Press, Chicago, IL.

Vander Wall, S. 1990. Food Hoarding in Animals. University of Chicago Press, Chicago, IL. 453 pp.

Witmer, G. 2007. The ecology of vertebrate pests and integrated pest management (IPM). Pp. 393-410 *in*: M. Kogan, and P. Jepson (Eds.), Perspectives in Ecological Theory and Integrated Pest Management. Cambridge University Press, Cambridge, UK.

Witmer, G., and J. D. Eisemann. 2007. Rodenticide use in rodent management in the United States: An overview. Proc. Wildl. Damage Manage. Conf. 12:114-118.

Witmer, G., and R. Engeman. 2007. Subterranean rodents as pests: The case of the pocket gopher. Pp. 287-299 *in*: S. Begall, H. Burda, and C. Schleich (Eds.), Subterranean Rodents: News from Underground. Springer-Verlag, Berlin, Germany.

Witmer, G. W., R. D. Sayler, and M. J. Pipas. 1996. Biology and habitat use of the Mazama pocket gopher (*Thomomys mazama*) in the Puget Sound Area, Washington. Northwest Sci. 70(2):93-98.

Witmer, G. W., and G. Proulx. 2010. Rodent outbreaks in North America. Pp. 253-267 *in*: G. R. Singleton, S. R. Belmain, P. R. Brown, and B. Hardy (Eds.), Rodents Outbreaks: Ecology and Management. IRRI, Los Banos, Philippines.

Witmer, G. W., and G. R. Singleton. 2010. Sustained agriculture: The need to manage rodent damage. Pp. 1-39 *in*: F. Wager (Ed.), Agricultural Production. Nova Science Publications, New York, NY.

Witmer, G., N. P. Snow, L. Humberg, and T. Salmon. 2009. Vole problems, management options, and research needs in the United States. Proc. Wildl. Damage Manage. Conf. 13:235-249.