Small Mammals: Pests or Vital Components of the Ecosystem[1]

Carolyn Hull Sieg[2]

ABSTRACT.--Small mammals regarded as "pests" should not be viewed separately from other components in the ecosystem. Small mammals have significant influences on vegetation and soils, exert predatory pressure on other animals, and provide food for predators. Future management efforts should include consideration of these diverse influences.

Careful evaluation of the role of small mammals and their relationships with their environment is necessary to fully appreciate the impact of control programs on the ecosystem. Small mammals regarded as "pests" should not be viewed separately from other components in the ecosystem. Rather, small mammals must be viewed in terms of their interrelationships with other components. Alteration of small mammal communities through control programs influence other components and ultimately the whole system.

Small mammal influences may be grouped as those effects on (1) vegetation, (2) soils, and (3) other animals. Vegetative influences may include effects on primary productivity, plant species composition, and decomposition rates of plant materials. Small mammals influence both physical and chemical properties of soils. Small mammals prey on insects and occasionally other small mammals, provide a prey base for carnivores, and modify their environments in such a way as to provide habitat for other animals.

INFLUENCES ON VEGETATION

Researchers have proposed various ways in which small mammals interact with plant communities. The main interactions can be categorized as those relating to primary productivity, plant species composition, plant stature and reproduction, and decomposition rates of plant materials.

Primary Production

Small mammal herbivores may consume as much as 60% (Migula et al. 1970) to 80% (Taylor and Loftfield 1942) of the total annual primary plant production. They may have localized, large-scale impacts on primary productivity during population explosions. However, the effect of direct consumption of plants by herbivores must be evaluated in terms of what portion of the primary production is actually available to the animal. Estimates of herbage consumption by small mammals ranged from <1% in northern shortgrass and midgrass sites to as much as 20% in desert grasslands (French et al. 1976). Harris (1971) estimated that 0.17-5.01% of the net primary production was transferred to the rodent trophic level. Hayward and Phillipson (1979) concluded that the impact of small mammal consumption on net or available primary production is negligible in most systems.

Light grazing by small mammals may stimulate plant production. For example, moderate grazing by voles (*Microtus oeconumus* and *M. middendorffit*) increased production of two plant species by stimulating new shoot growth (Smirnov and Tokmakova 1971, 1972). Regrowth of rye grass (*Lolium perenne*) that had been grazed by hispid cotton rats (*Sigmodon hispidus*) was faster than regrowth of grass that had been mechanically clipped (Howe et al. 1982). The authors speculated that either a biochemical agent in saliva or the specific manner of tissue removal by the cotton rats stimulated regrowth of the rye grass.

Plant Species Composition

Small mammals have been credited with changing plant community composition and species distribution. Rodents and rabbits have been cited as major agents responsible for range destruction (Taylor 1936). Other authors (e.g., Smith 1940) viewed the presence of these small mammals as a symptom of poor range condition, rather than a cause. Small mammals have been credited with assisting in the control of undesirable plants. Plant communities in Montana, Utah, and Nevada were altered by extensive damage to

---

[1]Paper presented at the 8th Wildlife Damage Control Workshop, April 28-30, 1987, in Rapid City, South Dakota.

[2]Sieg is Wildlife Biologist with the Rocky Mountain Forest and Range Experiment Station, Rapid City, South Dakota, in cooperation with the South Dakota School of Mines and Technology. The Station's headquarters is in Fort Collins, in cooperation with Colorado State University.

big sagebrush (Artemisia tridentata) during cyclic population peaks of voles (Microtus spp.) (Mueggler 1967, Frischknecht and Baker 1972). Control of pocket gophers (Thomomys talpoides) in western Colorado resulted in an increase of perennial forbs (Turner 1969); grass and sedge densities were higher in areas where gophers were present in Utah (Ellison and Aldous 1952). However, small mammal herbivory may also reduce densities of plants viewed as "beneficial" by land managers. Selective grazing by meadow mice (Microtus californicus) kept the habitat open and increased plant species diversity; when mice were excluded grasses increased and became dominant (Batzli and Pitelka 1970).

Small mammals can also alter plant community composition and species distribution by consuming and caching seeds. Rodents have been blamed for poor establishment of seeded plants and large scale failures of tree crops (Smith and Aldous 1947, Gashweiler 1970). Small mammals can further influence plant community composition by heavily grazing or damaging plants, and thus reducing their ability to produce seeds (Batzli and Pitelka 1970). Severe grazing by montane meadow mice (Microtus montanus) and deer mice (Peromyscus maniculatus) decreased biomass and seed production of cheatgrass (Bromus tectorum) in eastern Washington (Pyke 1986).

Seed caching activities can alter plant distribution by either increasing or decreasing survival of plants. The harvest and storage of grass seeds by meadow mice was estimated to reduce seed fall of preferred food plants by 70% in some areas in California (Batzli and Pitelka 1970). Yet, dispersal of seeds by small mammals can result in increased germination and survival. Seeds are often moved to better germination sites and seeds that normally have a "clumped" distribution pattern (as below the parent plant) are often scattered, or consumed, resulting in less dense stands (Reichman 1979). West (1968) estimated that 50% of the bitterbrush (Purshia tridentata) and 15% of the ponderosa pine (Pinus ponderosa) plants in central Oregon resulted from rodent seed caches. Consumption of wild oats (Avena fatua) and wild barley (Hordeum leporinum) seeds by meadow mice and house mice (Mus musculus) reduced densities of these two plants by 62% and 30%, respectively, allowing for increases in plant size and seed production of wild barley, Italian ryegrass (Lolium multiflorum), and bromegrasses (Bromus mollis and B. diandrus) (Bochert and Jain 1978).

Some organisms may be dependent on small mammals for seed or spore dispersal. Truffles and other hypogeous fungi depend on mammal and invertebrate mycophagy for spore dispersal (Fogel and Trappe 1978). Small mammals may serve as effective agents in the dispersal of mycorrhizal fungi and nitrogen-fixing bacteria. Viable nitrogen-fixing bacteria, yeast, and spores of mycorrihizal fungi all survived passage through the digestive tracts of forest rodents captured in western Oregon (Li et al. 1986). These results suggest that small mammals can innoculate recently disturbed soils, as after fires (Li et al. 1986) and in mined areas (Sieg et al. 1986). In this manner, pioneering small mammals may help initiate plant succession and increase survival of new plants.

The rate of plant succession may be affected by small mammal burrowing and feeding activities. Prairie dog mounds disrupt grass associations and provide bare soil for the invasion of lower successional plants. Pocket gopher mounds provide bare soil on which secondary plant succession may begin (Larrison 1942), thereby increasing the diversity of plants (Laycock 1958). Investigations following the Mount St. Helens eruption suggest that northern pocket gophers (Thomomys talpoides) may be an important agent in determining succession in volcanically disturbed areas. Pocket gophers bring pre-eruption soils to the tephra surface; plant survival on the pocket gopher mounds has exceeded survival on adjacent areas (Anderson and MacMahon 1985). Selective herbivory by small mammals can also alter plant successional rates. Rodents may aid in the recovery of overgrazed grasslands by selectively grazing on "weedy" plant species (Gross 1969). Grazing by California ground squirrels (Spermophilus becheyi) decreased the abundance of filaree (Eroduim botrys) and lupine (Lupinus bicolor) on Californian grasslands, while smooth bromegrass, a grass of higher successional stage than the forbs, increased (Horn and Fitch 1942).

Decomposition of Plant Materials

Small mammals can influence the rate of decomposition of organic materials by adding green herbage and excrements to the litter layer and by reducing the particle size of vegetative material. They are more efficient in effecting the mineralization of organic matter than either insects or ungulates (Golley et al. 1975). As much as 58% of the total herbage harvested by small mammmals on a shortgrass prairie was not consumed (Scott et al. 1979). These "wastage" activities may be important in accelerating decomposition rates of plant materials. Green plant material that becomes litter decomposes more rapidly that brown plant material (Grant and French 1980). Voles affect decomposition rates by altering microclimatic conditions in the litter layer and by deposition of excrements and vegetative cuttings into litter layers, which increases microorganism growth (Zlotin and Kodashova 1974). Reduction of particle size of living and dead vegetative material by small mammals also increases decomposition rates.

INFLUENCES ON SOILS

Soil structure and chemical composition are affected by the activities of small mammals. Soil structure is largely influenced by burrowing activities. Burrowing and the addition of feces and urine to the soil influence soil chemical composition through changes in nutrient and mineral cycling rates and pathways.

Soil Structure

Soil structure may be altered as small mammals burrow, bringing large quantities of mineral soil

to the surface. Pocket gophers are reported to excavate 18 metric tons of soil material per hectar per year (Hole 1981). Abaturov (1968) estimated that mole burrows covered 36% of woodland ground surface, which resulted in increased soil porosity and drainage, and altered soil water holding capacities. Pocket gophers tended to increase porosity and lower bulk density of soils in a subalpine grassland in Utah (Laycock and Richardson 1975). However, in seeded mountain ranges in Utah (Julander et al. 1959), pocket gopher activity packed the soil surface, lowered infiltration rates, and decreased available soil moisture.

Mima mound microrelief is another modification of the physical structure of the environment that has been attributed to small mammals. These mounds are characterized by a lower bulk density, less soil structure, and increased water permeability compared with neighboring undisturbed soil (Ross et al.1968). Soil mounds resulting from small mammal burrowing are strongly heated, and the surface crust that rapidly forms prevents evaporation. As a result, at depths of 5-20 cm the water content of the soil under mounds is 7-8% higher than that at corresponding depths in virgin soil (Zlotin and Kodashova 1974).

Chemical Composition

The most significant role of small mammals may be their effect on the chemical composition of soils, particularly the addition and incorporation of nitrogen (Taylor 1935). Soil chemical composition can be altered by the addition of small mammal excreta and by the upward displacement of nutrients through the soil profile. Feces and urine add to the organic matter content in soils, increase available nitrogen levels, and possibly influence the growth of Azotobacter (Kucheruk 1963 [cited in Hayward and Phillipson 1979]). Greene and Reynard (1932) estimated that the average kangaroo rat (Dipodomys spectabilis) burrow contained 2 kg of nitrate. Small mammals influenced the nitrogen flux on shortgrass prairies more than any other vertebrate, but less than either belowground or aboveground invertebrates (Woodmansee et al. 1978).

The concentration of other minerals may also be influenced by small mammal activities. High concentrations of soluble calcium, magnesium, and bicarbonate were reported in kangaroo rat burrows by Greene and Reynard (1932). Mole (Talpa europea) burrowing returned large quantities of leached calcium and magnesium to the zone of intense plant root activity (Dinesman 1967). Older prairie dog mound soils had higher pH values, and phosophorous values equal or greater than adjacent nonmound soils (Carlson and White 1987).

INFLUENCES ON OTHER ANIMALS

Small Mammals as Predators

Small mammals function as secondary consumers in the ecosystem by preying on invertebrates and on other mammals, which may have direct impacts on prey populations and indirect influences on primary production. Insectivorous species may exert a regulatory effect on invertebrate populations; small mammals consumed a high percentage of invertebrate populations in nearly all grassland sites studied by French et al. (1976). Carnivory has been shown to influence prey species densities. Hayward and Phillipson (1979) estimated that weasels (Mustela nivalis) consumed as much as 14% of the small mammal production, resulting in a reduction in the impact of small mammals on the rest of the ecosystem.

Secondary consumption may indirectly influence primary production. Plant consumption by invertebrate herbivores may be reduced by the insectivorous feeding habits of small mammals. Destruction of large numbers of larch sawfly larva by shrews was reported by Buckner (1964). Small mammal predation may serve to reduce invertebrate species that are themselves predators of phytophagous insects. Field mice (Apodemus sylvaticus) were responsible for a 50% reduction in an overwintering population of Hymenopteran cocoons (Obtrel et al. 1978). Interactions between insectivorous mammals and their food sources have received less attention than the interactions of small animals with primary production food sources, and therefore the extent to which invertebrate populations are regulated by insectivory is largely speculative.

Small Mammals as Prey

Small mammals serve as a food supply for a large number of predators and can exert significant influence on predator population cycles. Small mammals, especially rodents, are characterized by high productivity rates, and thus, even at relatively low densities, are an important source of food for predators. Densities of small mammals can have profound impacts on the reproductive potential of some predators. For example, the proportion of tawny owls (Strix aluco) that bred each year in England varied from 0 to 80%, according to the number of mice and voles present (Southern 1970). Several authors have documented cases where population levels of predators can be traced to small mammal densities. For example, population declines in black-tailed jackrabbits (Lepus californicus) induced significant decreases in numbers of coyotes (Canis latrans) in northwestern Idaho and southern Idaho (Clark 1972) and kit foxes (Vulpes macrotis) in western Utah (Egoscue 1975). Raptors, such as the great-horned owl (Bubo virginianus), may increase as much as five-fold during years of high densities of snowshoe hares in Alberta (McInvaille and Keith 1974). Further, population outbreaks of small mammals can induce predators to switch from preferred prey, thus reducing predation on some game species (Leopold 1933).

Small Mammals as Home Builders

Small mammals also influence other animals and arthropods by altering the environment in ways that provide habitat for other species. For example, bird densities and species richness were higher on prairie dog towns than on adjacent mixed-grass communities in South Dakota (Agnew et al. 1986).

Prairie dog burrows provide nest sites and escape cover for burrowing owls (Athene cunicularis), prairie rattlesnakes (Crotalus viridis viridis), and a variety of small mammals and arthropods (Costello 1969). Mounds made by moles (Scalopus spp.) become habitats of such animals as arthopods, amphibians, and reptiles (Hole 1981).

SUMMARY

Management decisions to control small mammals usually stem from perceived negative values associated with the offending species. However, as managers increasingly focus on ecosystem management, the positive role of small mammals on vegetation, soils, and other animals may be of interest. Further, public interest in a diversity of habitats and animals should induce managers to balance animal control efforts with efforts to maintain diversity in ecosystems. Small mammals can have significant influences on vegetation and soils, exert predatory pressure on insects and other mammals, and also provide food for other predators. It appears that small mammals fill important and perhaps indispensible roles in ecosystem function. They are interconnected in complex ways with other biotic and abiotic components of the ecosystem, and future management efforts should focus on these relationships to a greater extent than in the past.

LITERATURE CITED

Abaturov, B. D. 1968. Importance of the digging activity of the mole (Talpa euorpaea L.) on soil cover and vegetation in broadleaf-fir forest. Pedobiologia 8:239-264.

Agnew, W., D. W. Uresk, and R. M. Hansen. 1986. Flora and fauna associated with prairie dog colonies and adjacent ungrazed mixed-grass prairie in western South Dakota. J. Range Manage. 39:135-139.

Anderson, D. C., and J. A. MacMahon. 1985. Plant succession following the Mount St. Helens volcanic eruption: facilitation by a burrowing rodent, Thomomys talpoides. Am. Midl. Nat. 114:62-69.

Batzli, G. O., and F. A. Pitelka. 1970. Influence of meadow mouse populations on California grassland. Ecology 51:1027-1039.

Bochert, M. I., and S. K. Jain. 1978. The effect of rodent seed predation on four species of California annual grasses. Oecologia 33:101-113.

Buckner, C. H. 1964. Metabolism, food capacity and feeding behavior in four species of shrews. Can. J. Zool. 42:259-279.

Carlson, D. C., and E. M. White. 1987. Effects of prairie dogs on mound soils. Soil Sci. Soc. Am. J. 51:389-393.

Clark, F. W. 1972. Influence of jackrabbit density on coyote population change. J. Wildl. Manage. 36:343-356.

Costello, D. F. 1969. The prairie world. Thomas Y. Crowell Co., New York.

Dinesman, L. G. 1967. Influence of vertebrates on primary production of terrestrial communities, p. 261-266. In K. Petrusewica (ed.). Secondary productivity of terrestrial ecosystems. Warsaw, Poland.

Egoscue, H. J. 1975. Population dynamics of the kit fox in western Utah. Bull. So. Calif. Acad. Sci. 74:122-127.

Ellison, L., and C. M. Aldous. 1952. Influence of pocket gophers on vegetation of subalpine grassland in central Utah. Ecology 33:177-186.

Fogel, R., and J. M. Trappe. 1978. Fungus consumption (mycophagy) by small animals. Northw. Sci. 52:1-31.

French, N. R., W. E. Grant, W. Grodzinski, and D. M. Smith. 1976. Small mammal energetics in grassland ecosystems. Ecol. Monogr. 46:201-220.

Frischknecht, N. C., and M. F. Baker. 1972. Voles can improve sagebrush rangelands. J. Range Manage. 25:415-425.

Gashweiler, J. S. 1970. Further study of conifer seed survival in a western Oregon clear cut. Ecology 51:849-854.

Golley, F. B., K. Petrusewicz, and L. Ryszkowski (eds). 1975. Small mammals: their productivity and population dynamics. Cambridge University Press, London.

Grant, W. E., and N. R. French. 1980. Evaluation of the role of small mammals in grassland ecosystems: A modeling approach. Ecol. Model. 8:15-37.

Greene, R. A., and C. Reynard. 1932. The influence of two burrowing rodents, Dipodomys spectabilis and Neotoma albigula, on desert soils in Arizona. Ecology 13:73-80.

Gross, J. E. 1969. The role of small herbivorous mammals in the functioning of the grassland ecosystem. p. 268-278. In R. L. Dix and R. G. Biedleman (eds). The grassland ecosystem: A preliminary synthesis. Range Sci. Dept. Sci. Ser. No. 2, Colorado State University, Fort Collins, CO.

Harris, L. D. 1971. A precis of small mammal studies and results in the grassland biome. p. 213-240. In N. R. French (ed). Preliminary analysis of structure and function in grasslands. Range Sci. Dept. Sci. Ser. No. 10. Co. State Univ., Fort Collins, CO.

Hayward, G. F., and J. Phillipson. 1979. Community structure and functional role of small mammals in ecosystems. p. 136-211. In Stoddard, D. M. (ed). Ecology of small mammals. Chapman and Hall, London.

Hole, F. D. 1981. Effects of animals on soil. Geoderma 25:75-112.

Horn, E. E., and H. S. Fitch. 1942. Interrelations of rodents and other wildlife of the range. The San Joaquin Experimental Range. Univ. Calif. Exp. Sta. Bull. 663:96-129.

Howe, J. G., W. E. Grant, and L. J. Folse. 1982. Effects of grazing by Sigmodon hispidus on the regrowth of annual rye-grass (Lolium perenne). J. Mammal. 63:176-179.

Julander, O., J. B. Low, and O. W. Morris. 1959. Influence of pocket gophers on seeded mountain range in Utah. J. Range Manage. 12:219-224.

Larrison, E. J. 1942. Pocket gophers and ecological succession in the Wenas region of Washington. Murrelet 23:34-41.

Laycock, W. A. 1958. The initial pattern of revegetation of pocket gopher mounds. Ecology 39:346-351.

Laycock, W. A., and B. Z. Richardson. 1975. Long-term effects of pocket gopher control on vegetation and soils of a subalpine grassland. J. Range Manage. 28:458-462.

Leopold, A. 1933. Game management. Scribner, New York.

Li, C. Y., C. Maser, Z. Maser, and B. A. Caldwell. 1986. Role of rodents in forest nitrogen fixation in western Oregon: another aspect of mammal-mycorrhizal fungus-tree mutualism. Great Basin Nat. 46:411-414.

McInvaille, W. B., Jr., and L. B. Keith. 1974. Predator-prey relations and breeding biology of the great-horned owl and red-tailed hawk in central Alberta. Can. Field Nat. 88:1-20.

Migula, P., W. Grodzinski, A. Jasinske, and B. Muialek. 1970. Vole and mouse plagues in south-eastern Poland in the years 1945 - 1967. Acta Theriol. 15:233-252.

Mueggler, W. F. 1967. Voles damage big sagebrush in southwestern Montana. J. Range Manage. 20:88-90.

Obtrel, R., J. Zejida, and V. Holisova. 1978. Impact of small rodent predation on an overcrowded population of Diprion pini during winter. Folia Zool. 27:97-110.

Pyke, D. A. 1986. Demographic responses of Bromus tectorum and seedlings of Agropyron spicatum to grazing by small mammals: occurrence and severity of grazing. J. Ecology 74:739-754.

Reichman, O. J. 1979. Desert granivore foraging and its impact on seed densities and distributions. Ecology 60:1085-1092.

Ross, B. A., J. R. Tester, and W. J. Breckenridge. 1968. Ecology of mima-type mounds in northwestern Minnesota. Ecology 49:172-177.

Scott, J. A., N. R. French, and J. W. Leetham. 1979. Patterns of consumption in grasslands. p. 89-105. In N. R. French (ed). Ecological Studies 32. Perspectives in grassland ecology. Col. State Univ., Fort Collins.

Sieg, C. H., D. W. Uresk, and R. M. Hansen. 1986. Seasonal diets of deer mice on bentonite mine spoils and sagebrush grasslands in southeastern Montana. Northwest Sci. 60:81-89.

Smirnov, V. S., and S. G. Tokmakova. 1971. Preliminary data on the influence of different numbers of voles upon the forest tundra vegetation. Ann. Zool. Fenn. 8:154-156.

Smirnov, V. S., and S. G. Tokmakova. 1972. Influence of consumers on natural phytocenoses' production variation. p. 122-127. In Wielgolaski, F. E., and T. Rosswall (eds). Tundra Biome. Proceedings of the IV International Meeting on the Biological Productivity of Tundra. Leningrad, Russia.

Smith, R. A. 1940. The effect of overgrazing and erosion upon the biota of the mixed-grass prairie of Oklahoma. Ecology 21:381-397.

Smith, C. F., and S. E. Aldous. 1947. The influence of mammals and birds in retarding artificial and natural reseeding of coniferous forests in the United States. J. Forestry 45:361-369.

Southern, H. N. 1970. The natural control of a populations of Tawny owls (Strix aluco). J. Zoology 147:197-285.

Taylor, W. P. 1935. Some animals relations to soils. Ecology 16:127-136.

Taylor, W. P. 1936. Some effects of animals on plants. Sci. Monthly 43:262-271.

Taylor, W. P., and J. V. G. Loftfield. 1942. Damage to range grasses by the zuni prairie dog. U.S. Dept. Agr. Bull. No. 1227:16.

Turner, G. T. 1969. Responses of mountain grassland vegetation to gopher control, reduced grazing, and herbicide. J. Range Manage. 22:377-383.

West, N. E. 1968. Rodent influenced establishment of ponderosa pine and bitterbrush seedlings in central Oregon. Ecology 49:1009-1011.

Woodmansee, R. G., J. L. Dodd, R. A. Bowman, F. E. Clark, and C. E. Dickinson. 1978. Nitrogen budget of a shortgrass prairie ecosystem. Oecologia 34:363-376.

Zlotin, R. E., and K. S. Kodashova. 1974. The role of animals in the biological cycle of the forest-steppe ecosystem. Science Publ. House, Moscow.