1-1-1994

Identification and Assessment of Wildlife Damage: an Overview

Richard A. Dolbeer
Denver Wildlife Research Center, USDA-APHIS

Nicholas R. Holler
US Fish and Wildlife Service, Auburn, AL

Donald W. Hawthorne
USDA-APHIS, Animal Damage Control

Richard A. Dolbeer
Project Leader
Denver Wildlife Research Center
USDA-APHIS-
Animal Damage Control
Sandusky, Ohio 44870

Nicholas R. Holler
Unit Leader
Alabama Cooperative Fish and
Wildlife Research Unit
US Fish and Wildlife Service
Auburn, Alabama 36849

Donald W. Hawthorne
Associate Deputy Administrator
USDA-APHIS-
Animal Damage Control
Washington, DC 20090

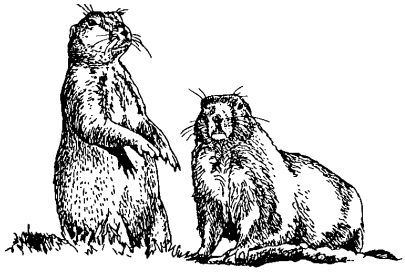
IDENTIFICATION AND ASSESSMENT OF WILDLIFE DAMAGE: AN OVERVIEW

Introduction

Wildlife management is often thought of in terms of protecting, enhancing, and nurturing wildlife populations and the habitat needed for their well-being. However, many species at one time or another require management actions to reduce conflicts with people or with other wildlife species. Examples include an airport manager modifying habitats to reduce gull activity near runways, a forester poisoning pocket gophers to increase tree seedling survival in a reforestation project, or a biologist trapping an abundant predator or competing species to enhance survival of an endangered species.

Wildlife damage control is an increasingly important part of the wildlife management profession because of expanding human populations and intensified land-use practices. Concurrent with this growing need to reduce wildlife-people conflicts, public attitudes and environmental regulations are restricting use of some of the traditional tools of control such as toxicants and traps. Agencies and individuals carrying out control programs are being more carefully scrutinized to ensure that their actions are justified, environmentally safe, and in the public interest. Thus, wildlife damage control activities must be based on sound economic, ecological, and sociological principles and carried out as positive, necessary components of overall wildlife management programs.

Wildlife damage control programs can be thought of as having four parts: (1) problem definition; (2) ecology of the problem species; (3) control methods application; and (4) evaluation of control. Problem definition refers to determining the species and numbers of animals causing the problem, the amount of loss or nature of the conflict, and other biological and social factors related to the problem. Ecology of the problem species refers to understanding the life history of the species, especially in relation to the conflict. Control methods application refers to taking the information gained from parts 1 and 2 to develop an appropriate management program to alleviate or reduce the conflict. Evaluation of control allows an assessment of the reduction in damage in relation to costs and impact of the control on target and nontarget populations and the environment. Increasingly, emphasis is being placed on integrated pest management whereby several control methods are combined and coordinated with other management practices in use at that time.



PREVENTION AND CONTROL OF WILDLIFE DAMAGE — 1994

Cooperative Extension Division
Institute of Agriculture and Natural Resources
University of Nebraska - Lincoln

United States Department of Agriculture
Animal and Plant Health Inspection Service
Animal Damage Control

Great Plains Agricultural Council
Wildlife Committee

Birds

Damage Assessment

Birds annually destroy many millions of dollars worth of agricultural crops in North America. The greatest loss appears to be from blackbirds feeding on ripening corn; a survey in 1981 indicated a loss in the United States of 330,000 tons (300,000 metric tons) worth $31 million (Besser and Brady 1986). Blackbird damage to sunflower crops in the upper Great Plains states was estimated at $5 million in 1979 and $8 million in 1980 (Hothem et al. 1988). Damage by various bird species to fruit crops, peanuts, truck crops, and small grains also can be severe in localized areas (Besser 1986). Fish-eating birds can cause major losses at fish rearing facilities. Economic losses from bird strikes to aircraft are perhaps more substantial than those in agriculture, at least $20 million annually each for US commercial air carriers (Steenblik 1983) and military aircraft (Merritt 1990).

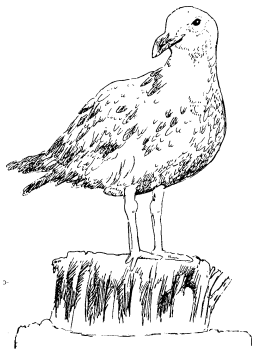
Unlike most mammals, which are secretive when causing damage, birds are often highly visible and their damage conspicuous. For this reason, subjective estimates often overestimate losses as much as tenfold (Weatherhead et al. 1982). Thus, objective estimates of bird damage to agricultural crops are important in order to accurately define the magnitude of the problem and to plan appropriate, cost-effective control actions (Dolbeer 1981).

To estimate losses due to birds in agricultural crops, one must devise a sampling scheme to select the fields that are to be examined and then determine the plants or areas to be measured in the selected fields (Stickley et al. 1979). For example, to objectively estimate the amount of blackbird damage in a ripening corn or sunflower field, the estimator should examine at least 10 locations widely spaced in the field. If a field has 100 rows and is 327 yards (300 m) long, the estimator might walk staggered distances of 33 yards (30 m) along 10 randomly selected rows (for example, 0 to 33 yards [0 to 30 m] in row 9, 34 to 65 yards [31 to 60 m] in row 20; and so on). In each 33-yard (30-m) length, the estimator should randomly select 10 plants and estimate the damage on each plant's ear or head. Bird damage to corn can be estimated by measuring the length of damage on the ear (DeGrazio et al. 1969) or by visually estimating the percent loss of kernels (Woronecki et al. 1980) and converting to yield loss per acre (ha). Fruit loss can be estimated by counting the numbers of undamaged, pecked, and removed fruits per sampled branch (Tobin and Dolbeer 1987). Sprouting rice removed by birds can be estimated by comparing plant density in exposed plots with that in adjacent plots with wire bird exclosures (Otis et al. 1983). The seeded surface area of sunflower heads destroyed by birds can be estimated with the aid of a clear plastic template (Dolbeer 1975).

Losses of agricultural crops to birds can be estimated indirectly through avian bioenergetics. By estimating the number of birds of the depredating species feeding in an area, the percent of the crop in the birds' diet, the caloric value of the crop, and the daily caloric requirements of the birds, one can project the total biomass of crop removed by birds on a daily or seasonal basis (White et al. 1985, Weatherhead et al. 1982).

Damage Identification

Most bird damage occurs during daylight hours. Thus, observation is the best way to identify the species causing damage. Presence of a bird species in a crop that is receiving damage does not automatically prove the species guilty, however. For example, large, conspicuous flocks of common grackles in sprouting winter wheat fields were found, after careful observation and examination of stomach contents, to be eating corn residue from the previous crop. Smaller numbers of starlings were removing the germinating wheat seeds (Dolbeer et al. 1979). Below, the characteristics of damage for various groups of birds are described.



Gulls

Several gull species have adapted to existing in proximity to people, taking advantage of landfills for food. For example, the ring-billed gull population in the Great Lakes region has been increasing at about 10% per year since the early 1970s (Blokpoel and Tessier 1984). Gulls are the most serious bird threat to flight safety at airports (Solman 1981). They are increasingly causing nuisance problems in urban areas by begging for food, defacing property, contaminating municipal water supplies, and nesting on rooftops. In rural areas, gulls sometimes feed on fruit crops, consume fish at aquaculture facilities, eat duck eggs and kill ducklings, and compete with threatened bird species for nest sites.

Blackbirds and Starlings

The term *blackbird* loosely refers to a group of about 10 species of North American birds, the most common of which are the red-winged blackbird, common grackle, and brown-headed cowbird. The starling, a European species introduced to North America in the late 1800s, superficially resembles native blackbirds and often associates with them. Together, blackbirds and starlings constitute the most abundant group of birds in North America, comprising a combined population of more than 1 billion (Dolbeer and Stehn 1983).

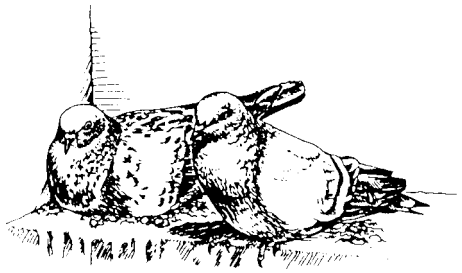
Blackbird damage to ripening corn, sunflower, and rice can be serious (Dolbeer 1994). Much of this damage is done in late summer during the milk or dough stage of seed development. The seed contents of corn are removed, leaving the pericarp or outer coat on the cob. Blackbird damage to sprouting rice in the spring can be important in localized areas.

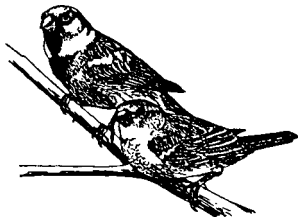
Starling depredations at feedlots in winter can cause substantial losses (Glahn et al. 1983, Besser et al. 1968). Although contamination of livestock feed by starling feces is often a concern of farmers, a study indicated this contamination did not interfere with food consumption or weight gain of cattle and pigs (Glahn and Stone 1984). Starlings can be serious depredators in fruit crops such as cherries and grapes.

Perhaps the greatest problem caused by blackbirds and starlings is their propensity to gather together in large, nocturnal roosting congregations, especially in winter. The noise, fecal accumulation, and general nuisance caused by millions of birds roosting together near human habitations can be significant (White et al. 1985). Roosting birds near airports can create a safety hazard for aircraft. Roost sites, if used for several years, can become focal points for the fungus that causes histoplasmosis.

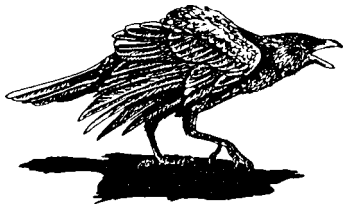
Pigeons and House Sparrows

Pigeons and house sparrows are urban and farmyard birds whose droppings deface and deteriorate buildings. Around storage facilities they consume and contaminate grain. Pigeons and sparrows may carry and spread various diseases to people, primarily through their droppings (Weber 1979). Droppings allowed to accumulate over several years are of particular concern





because they may harbor spores of the fungus that causes histoplasmosis. House sparrows can damage small grain crops but this is normally of economic concern only around agricultural experiment stations with small but valuable research plots (Royall 1969). Sparrows build bulky grass nests in buildings, drain spouts, and other sites where they can cause fire hazards or other problems.



Crows, Ravens, and Magpies

Crows, ravens, and magpies are well-known predators of eggs and nestlings in other birds' nests. In certain situations, these species kill newborn lambs or other livestock by pecking their eyes (Larsen and Dietrich 1970). Magpies sometimes peck scabs on freshly branded cattle.

Crows occasionally damage agricultural crops such as sprouting and ripening corn, apples, and pecans. Most of this loss is localized and minor. Crow damage to apples can be distinguished from damage by smaller birds by the deep (up to 2 inches [5 cm]), triangular peck holes (Tobin et al. 1989). Roosting congregations of crows in trees in parks and cemeteries sometimes cause nuisance problems because of noise and feces.

Herons, Bitterns, and Cormorants

These species sometimes concentrate at fish-rearing facilities and cause substantial losses (Salmon and Conte 1981). Salmon smolts released in rivers in the northeastern United States have suffered heavy depredation by cormorants. In recent years, double-crested cormorants have caused serious losses at commercial fish ponds in the southern United States (Stickley and Andrews 1989). Nighttime observations are sometimes necessary to determine the depredating species because herons and bitterns will feed at night.

Hawks and Owls

The raptors most often implicated in predation problems with livestock (primarily poultry and game farm fowl) are goshawks, red-tailed hawks, and great-horned owls (Hygnstrom and Craven 1994). Unlike mammalian predators, raptors usually kill only one bird per day. Raptor kills usually have bloody puncture wounds in the back and breast. Owls often remove the head. Raptors generally pluck birds, leaving piles of feathers. Plucked feathers with small amounts of tissue clinging to their bases were pulled from a cold bird that had probably died from other causes and was simply scavenged by the raptor. If the base of a plucked feather is smooth and clean, the bird was plucked soon after dying. Because raptors have large territories and are not numerous in any one area, the removal of one or two individuals will generally solve a problem.

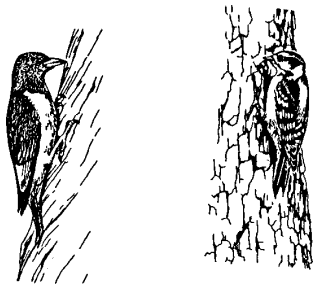
Golden Eagles

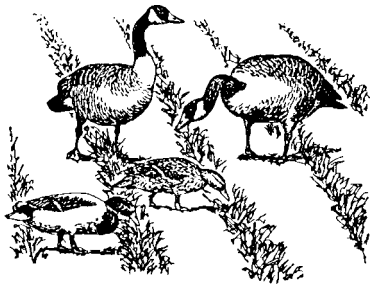
Golden eagles occasionally kill livestock, primarily lambs and kids on range. This predation can be locally severe in the sheep-producing areas from New Mexico to Montana (Phillips and Blom 1988).

Close examination is needed to identify an eagle kill. Eagles have three front toes opposing the hind toe, or hallux, on each foot. The front talons normally leave punctures about 1 to 2 inches (2.5 to 5.0 cm) apart in a straight line or small "V" and the wound from the hallux will be 4 to 6 inches (10 to 15 cm) from the middle toe. In contrast, mammalian predators almost always leave four punctures or bruises from the canine teeth. Talon punctures are usually deeper than tooth punctures and there is seldom any crushing of tissue between the talon punctures. If a puncture cannot be seen from the outside, skin the carcass to determine the pattern of talon or tooth marks. Often a young lamb is killed with a single puncture from the hallux in the top of the skull and the three opposing talons puncturing the base of the skull or top of the neck (O'Gara 1978, O'Gara 1994).

Woodpeckers

Woodpeckers at times cause damage to buildings with wood siding, especially cedar and redwood (Evans et al. 1983). The birds peck holes to locate insects, store acorns, or establish nest sites. They also damage utility poles. Sapsuckers attack trees to feed on the sap, bark tissues, and insects attracted to the sap. This feeding can sometimes kill the tree or degrade the quality of wood for commercial purposes (Ostry and Nicholls 1976). Woodpeckers occasionally annoy homeowners by knocking on metal rain gutters and stove pipes to proclaim their territories.





Ducks, Geese, and Sandhill Cranes

Damage by ducks and cranes to swathed or maturing small grain crops during the fall harvest is a serious localized problem in the northern Great Plains region (Knittle and Porter 1988). Damage occurs from direct consumption of grain and from trampling, which dislodges kernels from heads. Losses from trampling may be at least double the losses from consumption (Sugden and Goerzen 1979).

Canada and snow geese that graze on winter wheat and rye crops can reduce subsequent grain and vegetative yields (Kahl and Samson 1984, Conover 1988). Canada geese can also cause serious damage to sprouting soybeans in spring and to standing corn fields in the autumn. Canada geese have adapted to suburban environments in the past 20 years, creating nuisance problems around parks and golf courses through grazing and defecation (Conover and Chasko 1985).

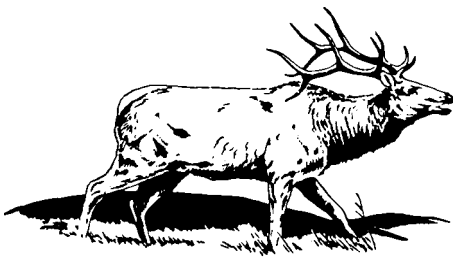
Ungulates (Deer, Elk, Moose)

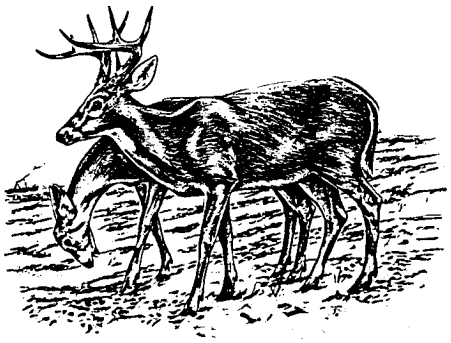
Damage Assessment

Ungulate damage to various agricultural, forestry, and ornamental crops caused by feeding, trampling, and antler rubbing is an increasing problem. Deer browsing in winter on buds of apple and other fruit trees can reduce yields the following year (Austin and Urness 1989) or adversely alter the growth pattern of tree limbs (Harder 1970). Similar browsing on nursery plants and in Christmas tree plantations can reduce or eliminate their market value (Scott and Townsend 1985). Browsing of hardwood saplings and young fir trees in regenerating forests can reduce growth rates, misshape trees, and even cause plantation failures (Crouch 1976, Tilghman 1989).

Damage to trees caused by antler rubbing can be severe (Scott and Townsend 1985). Small trees (1/2 to 1 inch [1.6 to 2.5 cm] in diameter at 6 inches [15 cm] above ground) with smooth bark, such as green ash, plum, and cherry, were preferred for antler rubbing by white-tailed deer in an Ohio nursery (Nielsen et al. 1982).

Objective estimates of economic loss from ungulate browsing and rubbing in orchards, nurseries, and reforestation projects are difficult to obtain. Losses in yield or tree value may accumulate for many years after damage occurs and vary with other stresses, including rodent damage, inflicted on the plants. In Ohio, growers reported average losses to deer in 1983 of $82 per acre ($204/ha) for orchards, $89 per acre ($219/ha) for Christmas tree plantings, and $108 per acre ($268/ha) in nursery plantings (Scott and Townsend 1985). Losses apparently





are in the millions of dollars annually in some US states (Black et al. 1979, Craven 1983*b*, Connelly et al. 1987).

Deer also feed on various agricultural crops, especially young soybean plants and ripening ears of corn. Hygnstrom and Craven (1988) estimated a mean loss of 2,397 pounds of corn per acre (2,680 kg/ha) for 51 unprotected corn fields in Wisconsin. Yield reductions in soybean fields are most severe when feeding occurs during the first week of sprouting (DeCalesta and Schwendeman 1978). Elk in some areas raid haystacks and cattle feedlots (Eadie 1954).

Damage Identification

Ungulates do not have an upper set of incisors. Thus, twigs or plants nipped by these hoofed species do not show the neat, sharp-cut edge left by most rodents and lagomorphs, but instead show a rough, shredded edge, and usually a square or ragged break. Pearce (1947) observed that deer in the Northeast seldom browse higher than 6 feet (1.8 m) from a standing position, but are able to reach up to 8 feet (2.5 m) by rearing up on their hind legs. Elk and moose browse to a height of about 10 feet (3 m). Deer seldom browse on branches more than 1 inch (2.5 cm) in diameter. Moose and elk will gnaw the bark of aspen trees. When male ungulates rub the velvet from their antlers, the scarring is generally confined to the trunk area up to 3 feet (1 m) high (Pearce 1947).

Rodents and other Small Mammals

Damage Assessment

Rodents and other small mammals are seldom observed in the act of causing damage, and their damage is frequently difficult to measure. Nonetheless, assessments of damage that have been made indicate rodents and nonpredatory small mammals cause tremendous annual losses of food and fiber in the United States. Forest animal damage in Washington and Oregon was estimated to total $60 million annually to Douglas fir and ponderosa pine and the potential reduction in the total value of forest resources was estimated to be $1.83 billion (Black et al. 1979, Brodie et al. 1979). Although these figures include losses attributable to ungulates, rodents and hares are responsible for much of the damage.

Miller (1987) surveyed forest managers and natural resource agencies in 16 southeastern states and estimated annual wildlife-caused losses, primarily by beavers, to be $11.2 million on 70 million acres (28.4 million ha). An additional $1.6 million was spent to control wildlife damage on this land. Arner and Dubose (1982) estimated that economic loss to beavers exceeded $4 billion over a 40-year period on 988,000 acres (400,000 ha) in the southeastern United States. Annual loss in Mississippi to nonimpounded timber was estimated to be $215 million over a period of at least 10 years (Bullock and Arner 1985).

Rats cause substantial losses to sugarcane. Lefebvre et al. (1978) estimated annual losses to be about $6 million ($95 per acre, [$235/ha]) in one-third of the area producing sugarcane in Florida. Hawaiian losses were reported to be in excess of $20 million per year (Seubert 1984). Ferguson (1980) estimated that in 1978, voles caused losses that approached $50 million to apple growers in the eastern United States. Losses of forage on rangelands to rodents, rabbits, and hares are also known to be extensive; however, accurate estimates of the monetary losses are difficult to obtain because of the nature of the damage and the wide area over which it occurs (Marsh 1985).

Pearson and Forshey (1978) compared yields of apple trees visibly damaged by voles to those not showing damage to determine the dollar losses in gross return per tree. Richmond et al. (1987) determined reductions in growth, yield, and fruit size of apple trees damaged by pine vole populations of known size maintained in enclosures around the trees.

An index of rodent damage to sugarcane was developed through sampling at harvest to determine the percent of stalks damaged (Lefebvre et al. 1978). Clark and Young (1986) established transects in corn fields and noted rodent damage to individual seedlings over a 10-day period. Forage losses have been estimated by comparing production on areas with and without rodents (Turner 1969, Foster and Stubbendieck 1980, Luce et al. 1981). Sauer (1977) used exclusion cylinders to determine losses of forage to ground squirrels. Alsager (1977) described a method to determine forage production reductions from pocket gopher damage. These methods are useful in evaluating efficacy of control techniques. However, loss estimates must be converted to accurate assessments of dollar loss to enable benefit-cost evaluation of control programs. This conversion is difficult given the vast acreages involved and the variability in rodent populations.

In some situations (for example, timber flooded by beaver, gopher damage to conifer seedlings, vole damage to apple trees), failure to initiate control may mean loss of the entire resource. Thus, potential loss in these situations is equal to the cost of replacement of the resource. In other situations, control may be necessitated irrespective of cost (for example, rats or mice in homes).

These examples illustrate the complexity of damage situations and the need for better damage assessment methods, an area of high priority for future research. Lack of methods for determining damage levels has been a serious impediment to the development of cost-effective control strategies.

Damage Identification

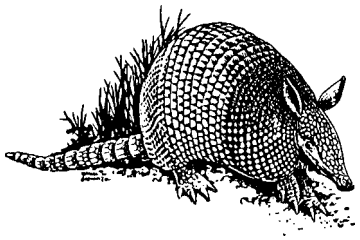
Most wild mammals are secretive and not easily observed; many are nocturnal. Often the investigator must rely on various signs, such as tracks, trails, tooth marks, scats, or burrows to determine the species doing the damage. Trapping may be necessary to make a positive identification of small rodents; frequently, more than one species is involved.

Characteristics of the damage may also provide clues to the species involved. In orchards, for example, major stripping of roots is usually caused by pine voles, whereas damage at the root collar or on the trunk up to the extent of snow depth is most often caused by meadow voles. In sugarcane, various species of rats gnaw stalks so that they are hollowed out between the internodes but usually not completely severed. Rabbits, in contrast, usually gnaw through the stalks, leaving only the ring-shaped internodes.

Damage to plants can generally be grouped as follows: root damage — pocket gophers and pine voles; trunk debarking—meadow voles, squirrels, porcupines, wood rats, rabbits, and mountain beavers; stem and branch cutting—beavers, rabbits, meadow voles, mountain beavers, pocket gophers, wood rats, squirrels, and porcupines; needle clipping—mice, squirrels, mountain beavers, porcupines, and rabbits; debudding—red squirrels and chipmunks. These characteristics can aid in identification of the species responsible, but positive identification should be made either by species-specific signs (tracks, hair, droppings) or by capture of individuals.

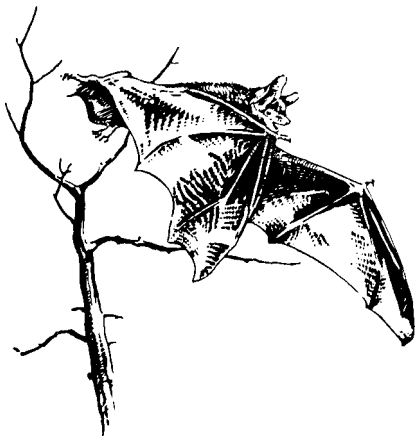
Armadillos

The armadillo has extended its range eastward and northward from Texas and is now found in all Gulf Coast states and parts of New Mexico, Oklahoma, Kansas, Arkansas, and Missouri (Humphrey 1974). Armadillos feed primarily on invertebrates obtained by rooting in ground cover. When rooting



takes place in lawns, golf courses, or gardens, economic damage results. There is also concern about the impact of armadillos on forest floor communities within their expanded range (Carr 1982).

Armadillo burrows under orchard trees can cause root damage or excessive aeration (Marsh and Howard 1990). Nuisance problems result when armadillos burrow under structures. Armadillos carry the bacterium that causes leprosy in humans, but their importance in transmission of the disease to humans has not been determined (Davidson and Nettles 1988).



Bats

Bats, the only mammals capable of true flight, eat vast quantities of insects. Only a few of the 40 species of bats found in the United States and Canada cause problems, primarily when they form roosts or maternity colonies in human dwellings or structures. Those most commonly encountered in pest situations are the little brown bat, big brown bat, Mexican free-tailed bat, pallid bat in the Southwest, and *Yuma myotis* in the West (Greenhall 1982, Frantz 1986). Species identification may be difficult but is important because several bat species are endangered and protected by state and federal law. Control operators unfamiliar with bat identification are urged to seek professional help from wildlife agencies or universities (Frantz 1986).

The presence of bats in a building is usually evidenced by noise (squeaking, scratching) and by the presence and distinctive pungent odor of the accumulated fecal droppings and urine. Bat feces are readily distinguished from those of rodents by odor, insect content, and the ease with which they are crushed (Greenhall 1982).

Many people are fearful of bats and panic in their presence. Bats occasionally contract rabies, and although few human deaths have resulted from bat-transmitted rabies (Greenhall 1982), contact with a rabid bat or a bite by a bat that escapes requires postexposure treatment of people and pets without current vaccinations (Frantz 1986). The fungal causative organism of histoplasmosis, a respiratory disease of humans, can develop where bat colonies are allowed to persist and guano deposits accumulate. Bats roosting near airports may be hazardous to aircraft (Kincaid 1975).

Beavers

Beaver damage is easily identified by the distinctive cone-shaped tree stumps resulting from their gnawing, and often by the presence of their dams and lodges. The latter might not be present, however, in ponds or reservoirs, or along swift mountain streams, where they burrow into banks. Usually, when beavers are active in an area, green sticks with the bark freshly peeled off may be found.

Damage caused by beavers results from feeding behavior (tree cutting) and their efforts to control water levels (dam building). Tree cutting in certain situations results in selective elimination of preferred tree species, such as aspen and cottonwood, from the vicinity (Beier and Barrett 1987). Loss of timber and crops from flooding is of much greater importance, however, especially in the southeastern United States where beaver populations have increased dramatically as a result of a

decline in trapping due to low pelt prices (Woodward 1985). Beavers often use sticks to plug road culverts or water-control structures in ponds and reservoirs. Additionally, beavers can cause extensive damage to levees and human-made dams by their burrowing.

Beavers are susceptible to infection by protozoan parasites (*Giardia* spp.) that can cause gastroenteritis and diarrhea in humans. Transmission to humans can be prevented by use of proper water treatment measures (Davidson and Nettles 1988).

Chipmunks

Occasionally, chipmunks damage grain fields, garden seeds, flower bulbs, and plants through burrowing and feeding. They infrequently destroy eggs and nestling birds (Eadie 1954). They can establish residence in or under human dwellings. Chipmunks cause reforestation problems by consuming seeds, seedlings, and the terminal buds of older plants, and by caching seeds, often in large quantities (Marsh and Howard 1990). In parts of the western United States, chipmunks are a potential reservoir for plague and are controlled in campgrounds (Marsh and Howard 1990). Chipmunks are easily observed due to their diurnal activity; their presence can also be determined by trapping.

Cotton Rats

The hispid cotton rat, a common species in the southern United States and in Mexico, is the species of cotton rat most often causing damage. Two other species have localized occurrences in Arizona and New Mexico. Cotton rats are primarily herbivorous, but they also prey on eggs and young of ground nesting birds (Hawthorne 1994). They undergo major population fluctuations. Most damage is a result of feeding in agricultural crops, especially melons and sugarcane.

Cotton rats are active day and night and, when abundant, are often observed. Their presence is also indicated by well developed runways through dense vegetation and the presence of grass cuttings 2 to 3 inches (5 to 8 cm) in length placed in piles. Pale greenish-yellow droppings, about 1/2 inch (0.9 cm) long and 1/4 inch (0.5 cm) wide, are sometimes present in the runway. Cotton rat sign is similar to that of voles but droppings, runways, and clippings of the cotton rat are usually larger (Hawthorne 1994). Cotton rats are often one of several rodent species causing damage in crops.

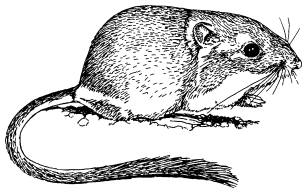
***Peromyscus* (Deer Mice, White-footed Mice)**

The genus *Peromyscus* is large, and one or more species is found in all parts of North America. These mice are nocturnal and active all year. *Peromyscus* populations may show large fluctuations. These mice are the most important seed predators in the Pacific Northwest, causing extensive damage in reforestation efforts (Sullivan 1978). Effects on reforestation have caused a shift to the use of hand-planted seedlings in many areas. *Peromyscus* also can cause significant losses to corn seedlings in conservation tillage systems but this damage may be offset by their consumption of harmful insects and weed seeds (Johnson 1986, Clark and Young 1986). *Peromyscus* may invade homes where they eat stored food and damage upholstered furniture or other materials shredded for use in nest building. They recently have been implicated in the transmission of an often fatal hantavirus to humans. Infections may occur through contact with mouse urine, feces, or saliva. Trapping with snap or live traps is the best method to determine the species present.

Ground Squirrels

Ground squirrels (genus *Spermophilus*), are important pest species in north central and western North America, causing serious losses of tree seeds and emergent seedlings. A careful search of an area showing damage will reveal opened seed hulls and caches. Ground squirrels can inflict serious damage to pastures, rangelands, grain fields, vegetable gardens, and fruit or nut crops. Their burrows can cause collapse of irrigation levees, increase erosion, and result in damage to farm machinery. They are also an important predator of waterfowl eggs in the prairie pothole region (Sargeant and Arnold 1984). They carry several diseases transmissible to humans, including plague; in plague endemic areas, ground squirrel control should be combined with ectoparasite control (Marsh and Howard 1990).

Ground squirrels are diurnal and easily observed (Marsh 1985). They hibernate and estivate, and have major dietary shifts during the year (Marsh 1985, 1986). Effective control strategies must consider these factors.



Kangaroo Rats

Kangaroo rats are competitors of livestock on arid western rangelands (Marsh 1985) when present in high populations, especially during drought. They can also retard recovery of overgrazed rangelands when cattle are removed (Howard 1994) and spread undesirable shrub species by caching of seeds (Reynolds and Glendening 1949, Marsh 1985). Kangaroo rats cause significant damage to alfalfa and corn on irrigated sandy soils by consuming newly planted seeds and clipping off seedlings (Howard 1994). Sorghum, other grains, and garden crops can also be damaged in local areas.

Several species of kangaroo rats are endangered. Kangaroo rats are nocturnal, but their burrow systems, with aboveground mounds and interconnecting runways, are readily observed. Snap trap surveys can identify the species present, provided the damage area is not within the range of one of the species listed as endangered.

Marmots

Marmots (woodchucks), like ground squirrels, can cause damage to many crops; forage production may be markedly reduced by marmot feeding and trampling (Marsh 1985). They damage fruit trees and ornamental shrubs by gnawing or scratching woody vegetation (Bollengier 1994). Their burrows, often located along field edges, can cause damage to farm machinery and injure livestock; when located along irrigation ditches they can cause loss of water. In suburban areas, burrows located under buildings or in landscaped areas cause problems (Marsh and Howard 1990). The presence of woodchucks is easily determined by direct observation of animals and burrows. During periods of forage growth, vegetation around burrows is noticeably shorter than in surrounding areas. Occupied burrows can be identified in spring by the presence of dirt pellets ranging from marble to fist size.

Voles

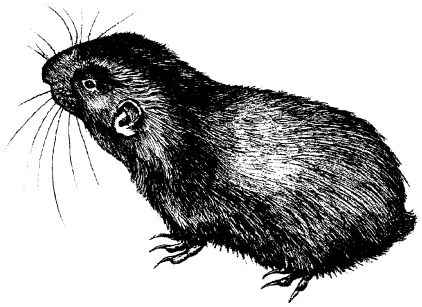
Voles (genus *Microtus*), also called meadow mice, field mice, and pine mice, cause extensive damage to forests, orchards, and ornamentals by gnawing bark and roots (Pearson and Forshey 1978, Byers 1984, Pauls 1986, Sullivan et al. 1987, O'Brien 1994). Tree or shrub damage usually occurs under snow or dense vegetation; the bark is gnawed from small trees near the root collar and up the trunk as far as the snow extends. Voles gnaw through small trees or shoots up to about 1/4 inch (0.6 cm) in diameter. Some species (for example, pine vole) also cause extensive damage to root systems; this damage may not be detected until spring when it is reflected in the condition of new foliage. Voles can also damage field and garden crops; when vole populations are high, these losses can be catastrophic (Clark 1984, Marsh 1985). Voles are carriers of plague and tularemia.

Vole populations are subject to large, rapid fluctuations. The presence of voles is most easily determined by searching for their runways and burrow systems. In orchards these can be found by pulling the grass and other debris from the bases of trees to expose the runways. Burrows of pine voles are usually subterranean. Gnawing on the trunks and roots of trees is usually less uniform than that of other rodents. Tooth marks can be at all angles, even on small branches, and may vary from light scratches to channels 1/10 inch (0.3 cm) wide, 1/12 inch (0.2 cm) deep, and 1/2 inch (1.3 cm) long. In hay crops, runways with numerous burrow openings, clipped vegetation, and feces, can be located in dense vegetation.

Moles

Moles feed primarily on soil invertebrates, especially earthworms and grubs (beetle larvae). About 20% of their food is plant material, which may include garden vegetables and small grains (Silver and Moore 1941). Voles and mice use the burrows of moles and can be responsible for some damage attributed to moles (Henderson 1994). Burrowing by moles may reduce production of forage crops by undermining and smothering vegetation, and by exposing root systems to drying. Their surface burrows can also plug harvesting machinery and contaminate hay and silage (Wick and Landforce 1962). Moles can damage lawns and golf greens extensively through burrowing.

The presence of moles can usually be detected by the mounds of soil thrown up from extensive tunnels dug in search of food and by the raised soil of surface burrows. Mole hills can be distinguished from pocket gopher mounds by their more rounded contour and the lack of a burrow entrance or soil plug (Eadie 1954).



Mountain Beavers

Mountain beavers cause serious economic loss by burrowing through and feeding on garden vegetables, berry plants, and young trees. They use drainage ditches for burrow sites, and their burrows may undermine roadways.

Mountain beavers are a major factor limiting reforestation in the Pacific northwest (Borrecco and Anderson 1980, Evans 1987*a*). Plantations are most susceptible to damage for 4 years after planting and when precommercially thinned at about 12 to 15 years (Evans 1987*a*). Mountain beavers clip

seedlings and gnaw saplings and the stems and bark of larger trees.

Mountain beavers normally clip seedlings through at a 45° angle. On small seedlings this clipping may be difficult to distinguish from rabbit damage; however, rabbits seldom clip stems larger than 1/4 inch (0.6 cm) in diameter or 20 inches (50 cm) above ground level, whereas mountain beavers often cut stems larger than 1/2 inch (1.3 cm) in diameter and up to 9 feet (3 m) above ground (Lawrence et al. 1961). Mountain beavers leave branch stubs, cut at a 45° angle, protruding from the main stem. The bark of the main stem shows horizontal tooth marks and vertical claw marks (Packham 1970). Runways and burrows are present in or near the damaged area.

Muskrats

Muskrats most often cause problems where people have created or manipulated wetlands or where wetlands border agricultural crops. The most serious damage results from burrows in pond dams, levees, and irrigation canals. The burrow entrance is below water level and penetrates the embankment at an upward angle to allow for a room above the water level. Damage is increased when the water level rises and the burrow is extended higher to provide a dry chamber, thereby increasing chances of washouts and cave-ins. At times, muskrats cause severe damage to grain, such as rice, and to garden crops growing near water. Muskrats are primarily vegetarians, but they will feed on aquatic animals where vegetation is limited (Miller 1994).

Muskrats commonly construct cone-shaped houses projecting 6 inches to 3 feet (15 to 90 cm) above the water surface. Muskrat presence is indicated by houses and burrow entrances. Underwater runs can be observed when the water is clear or after a winter draw down of ponds or reservoirs (Miller 1994).

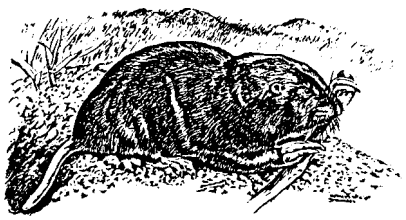
Nutria

Nutria are semiaquatic, herbivorous mammals that feed on aquatic plants, roots, seeds, and crops grown close to waterways. The greatest losses from this introduced rodent are to sugarcane and rice, especially in fields adjacent to Gulf Coast marshes (LeBlanc 1994). Nutria may severely impede cypress regeneration (Conner and Toliver 1987). They also damage wooden structures and floating marinas.

Nutria presence is evidenced by tracks, droppings, and trails to and from the damage area. Nutria also may be observed in the damage area.

Pocket Gophers

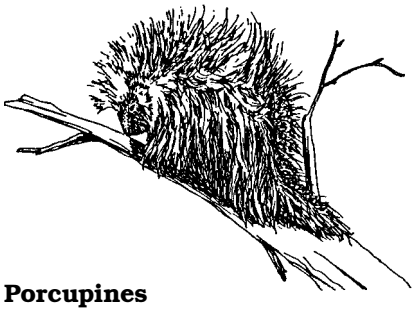
Pocket gophers cause substantial damage to agricultural crops, lawns, rangeland, and tree plantings. Gophers feed primarily on the underground portions of plants and trees. Damage often is undetected until a tree shows aboveground signs of stress; by then damage is frequently lethal (Cummings and Marsh 1978). Pocket gophers may also damage plastic irrigation lines on agricultural lands as well as underground pipes, cables, and electric wires.



On rangeland, soil disturbance and mound building by pocket gophers result in increased plant diversity and a replacement of perennial by annual grasses (McDonough 1974, Foster and Stubbendieck 1980, Marsh 1985). They can greatly reduce the carrying capacity of rangeland for livestock. They can be a serious pest in alfalfa by feeding on the leaves, stems, and roots (Marsh 1985). Gopher mounds can cause equipment breakage and increased wear on haying machinery. Gopher tunnels result in water loss in irrigated areas (Case and Jasch 1994).

Pocket gophers are a major impediment to reforestation in the western United States (Crouch 1986). During winter pocket gophers often forage above ground by tunneling in the snow. Coniferous trees have been found debarked to a height of 12 feet (3.5 m) by pocket gophers working under the snow (Capp 1976). Gophers also fill some of the snow tunnels with soil, thus forming long tubular "casts" that remain after the snow melts.

Pocket gopher presence is easily determined by fan-shaped soil mounds in contrast to the conical mounds of moles. Burrow entrances are usually plugged. Aboveground debarking injuries caused by pocket gophers show small tooth marks, differing from the distinct broader grooves left by porcupines, and the finely gnawed surface caused by meadow voles. Gophers will at times pull saplings and vegetation into the burrow.

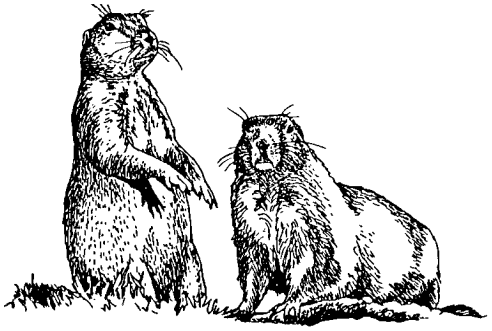


Porcupines

Porcupines are usually nocturnal and are active all year. During summer, porcupines often feed on succulent plants, including garden and truck crops in open meadows, fields, and along the banks of streams and lakes. Greatest damage is caused in winter

when porcupines feed on the inner bark of trees (Marsh and Howard 1990). Girdling in the upper trunk of trees often results in dead tops (Evans 1987*b*). Basal girdling may occur on seedlings. Porcupines are attracted to anything containing perspiration salt: saddles, harnesses, belts, and tool handles.

Porcupine damage can be identified by broad incisor marks on the exposed sapwood. Abundant oblong droppings about 1 inch (2.5 cm) long can be found under freshly damaged trees. Clipped twigs and tracks may also be found on snow. Top girdling in pine results in trees with a characteristic brushy crown.



Prairie Dogs

Prairie dogs were widespread on the Great Plains throughout the 1800s and reached peak numbers around 1900 after reduction of natural predators and establishment of cattle grazing. By 1921 the area occupied by prairie dogs was estimated to be 99 million acres (40 million ha). By 1971, following intensive control efforts, only 1.5 million acres (0.6 million ha) were occupied. Populations have been expanding in recent years, commensurate with reduced control efforts (Fagerstone 1981).

Prairie dogs damage rangelands and pastures by clipping vegetation for food and nesting material and by clearing cover from the vicinity of burrows (Hygnstrom and Virchow 1994). This activity not only reduces available forage, but can alter species composition of the vegetation in favor of forbs. Competition with cattle does not always exist, however, and in some situations beneficial effects of prairie dogs offset competition. Therefore, each conflict situation should be evaluated individually (Fagerstone 1981).

Crops planted near prairie dog colonies can receive serious damage from feeding and trampling. Also, damage to irrigation systems is common, and badgers digging for these rodents cause even greater damage. The burrows and mounds created by prairie dogs can increase soil erosion, cause drainage of irrigation water, and result in damage to farm implements. Prairie dogs also serve as a reservoir for plague (Hygnstrom and Virchow 1994).

Prairie dog colonies provide habitat for other species, such as the endangered black-footed ferret. All lethal control should be preceded by a careful survey to ensure that ferrets are not present. The Utah prairie dog is a threatened species and should not be controlled.

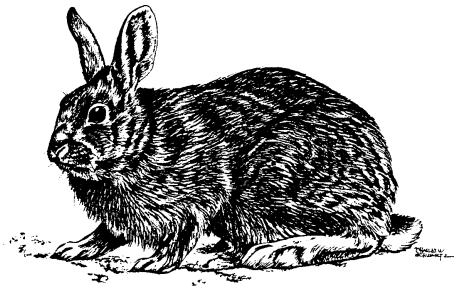
Prairie dog colonies are easily identified by the conical mounds around burrow entrances and by the presence of the easily observed animals.

Rabbits and Hares

Rabbits and hares can damage or completely destroy tree plantings, gardens, ornamentals, agricultural crops, and rehabilitated rangeland. In winter, they strip bark from and debud fruit trees, conifers, and other trees and shrubs (Craven 1994).

Rabbits are known vectors of tularemia, which is transmissible to humans, and they may carry larvated eggs of several ascarid roundworms that can produce disease if accidentally ingested (uncooked) by humans (Davidson and Nettles 1988).

Jackrabbits also damage orchards, gardens, ornamentals, and some agricultural crops, especially in areas adjacent to rangeland, and most frequently when natural vegetation is dry (Knight 1993). Jackrabbit populations show



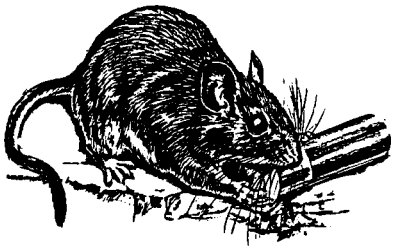
large fluctuations, and, at times of high density, damage to rangeland vegetation and competition with livestock can be severe.

Trees clipped by rabbits and hares have a clean oblique knifelike cut on the stem. Rabbits and hares usually clip stems 1/4 inch (0.6 cm) in diameter or less at a height not more than 20 inches (50 cm) above the ground (Lawrence et al. 1961). Repeated clipping will deform seedlings. Rabbits and hares can often be observed at damage sites along with their tracks, trails, and droppings.

Tree Squirrels

Tree squirrels may be divided into three groups: large tree squirrels (gray, fox, and tassel-eared), pine squirrels (red and Douglas), and flying squirrels (northern and southern) (Jackson 1994). Squirrels eat plants and fruit, dig up newly planted bulbs and seeds, strip bark and leaves from trees and shrubs, invade homes, and consume bird eggs (Jackson 1994, Hadidian et al. 1987). They cause problems by shorting out transformers and gnawing on power and telephone lines (Marsh and Howard 1990, Hamilton et al. 1987).

Squirrels can often be observed at the damage site. Damage to conifer seed is indicated by green, unopened cones scattered on the ground under mature trees and by the accumulated cone scales and "cores" at feeding stations. Bark stripping can be observed in trees and bark fragments are often found on the ground, as are the tips of twigs and small branches.



Wood Rats

Wood rats, also called pack rats, brush rats, or trade rats, are attracted to food supplies left in buildings and will remove small objects such as spoons, forks, knives, and other items, sometimes leaving sticks or other objects "in trade." They often construct conspicuous stick houses in cabins, abandoned vehicles, or in the upper branches of trees (Marsh and Howard 1990, Salmon and Gorenzel 1994). They will shred mattresses and upholstery.

Wood rats are agile climbers and consume fruits, seeds, and green foliage of herbaceous and woody plants (Lawrence et al. 1961). They strip and finely shred patches of bark from conifers and fruit trees to line nest chambers (Hooven 1959). They will also clip small branches. Their damage may be confused with that of tree squirrels and porcupines; however, wood rats leave a relatively smooth surface with a few scattered tooth marks, and tend to litter the ground beneath the tree less than tree squirrels.

Several subspecies of wood rats are endangered. Local regulations should be checked before control efforts are undertaken.

Commensal Rodents

The three species of commensal rodents (those that live primarily around human habitation) are Norway rats, roof (black) rats, and house mice. These omnivorous rodents consume millions of bushels of grain each year in the field, on the farm, in the elevator, mill, store, and home, and in transit. They also waste many more millions of bushels by contamination. These rodents typically drop 25 to 150 pellets and void 1/3 to 2/3 ounce (10 to 20 ml) of urine every 24 hours, and constantly shed fine hairs.

Rats cause extensive damage to sugarcane in Hawaii and Florida, and roof rats are serious pests in Hawaiian macadamia nut plantations. These rodents will feed on poultry chicks and occasionally even attack adult poultry, wild birds, newborn pigs, lambs, and calves. Health departments annually report hundreds of human babies bitten by rats. Many viral and bacterial diseases are transmitted to humans by rodent feces and urine that contaminate food and water (Weber 1982).

Gnawing by rodents causes considerable property damage. Fires are sometimes started when rats and mice gnaw the insulation of electric wiring. They will also use materials such as oily rags and matches for building nests, which can result in fires by spontaneous combustion. Extensive damage to foundations and concrete slabs is sometimes done when Norway rats burrow under buildings. Burrows into dikes and outdoor embankments cause erosion.

Signs of commensal rodents are gnawing, droppings, tracks, burrows, and darkened or smeared areas along walls where they travel. Reviews of problems caused by these species and methods of control are provided by Meehan (1984), Jackson (1987), Baker et al. (1993), Marsh (1994), and Timm (1994).

Carnivores and other Mammalian Predators

Damage Assessment

Mammalian predators have always been a concern to livestock producers. Wade (1982) estimated that the direct loss of sheep and goats to coyotes in the United States ranged from $75 million to $150 million annually. Pearson (1986), using a summary of other studies and surveys, estimated the loss of sheep, lambs, and goats to predators (primarily coyotes) to be $68,160,000 in the 17 western states in 1984. Terrill (1988), using data from all 50 states, reported that annual losses of sheep and lambs to coyotes and other predators ranged from $69 million to $83 million in 1985 to 1987. In 1990, 490,000 sheep and lambs valued at $21.7 million and 129,400 goats valued at $5.6 million were lost to predators in the United States (NASS 1991). In 1991, the National Agricultural Statistics Service estimated that predators killed 106,000 cattle and calves in the United States, valued at $41.5 million (NASS 1992). Losses of poultry to predators, although not well documented, are also thought to be substantial.

Mammalian predators, especially red foxes, striped skunks, raccoons, and mink, seriously impact waterfowl nesting success in small wetland areas surrounded by agricultural lands. A study in North Dakota indicated nesting success of only 8% for mallards on such wetlands, half of what was needed to sustain the population (Cowardin et al. 1985). The red fox is apparently the most serious waterfowl predator because it is adept at catching nesting hens as well as destroying eggs (Sargeant et al. 1984).

Damage Identification

Predation is rarely observed; therefore, the accurate assessment of losses to specific predators often requires careful investigative work. The first action in determining the cause of death of an animal is to check for signs on the animal and around the kill site. Size and location of tooth marks will

often indicate the species causing predation. Extensive bleeding usually is characteristic of predation. Where external bleeding is not apparent, the hide can be removed from the carcass, particularly around the neck, throat, and head, and the area checked for tooth holes, subcutaneous hemorrhage, and tissue damage. Hemorrhage occurs only if skin and tissue damage occurs while the animal is alive. Animals that die from causes other than predation normally do not show external or subcutaneous bleeding, although bloody fluids may be lost from body openings (Bowns 1976). Animal losses are easiest to evaluate if examination is conducted when the carcass is still fresh (Wade and Bowns 1982).

Animals may not always be killed by a throat attack, but may be pulled down from the side or rear. Blood is often on the sides, hind legs, and tail areas. Calves can have their tails chewed off and the nose may have tooth marks or be completely chewed by the predator when the tongue is eaten (Bowns 1976).

Tracks and droppings alone are not proof of depredation or of the species responsible. They are evidence that a particular predator is in the area and, when combined with other characteristics of depredation, can help determine what species is causing the problem.

Badgers

Badgers eat primarily rodents such as mice, prairie dogs, pocket gophers, and ground squirrels. They will also prey on rabbits, especially the young. Badgers destroy nests of ground-nesting birds and occasionally kill small lambs and poultry, parts of which they sometimes bury in holes resembling their dens. Dens in crop fields may slow harvesting or cause damage to machinery, and the digging can damage earthen dams or dikes (Lindzey 1994).

Badgers usually eat all of a prairie dog except the head and fur along the back. This characteristic probably holds true for most of the larger rodents they eat; however, signs of digging near prey remains are the best evidence of badgers. Badger tracks often appear similar to coyote tracks but on close examination they are distinctively "pigeon-toed" with impressions from the long toenails apparent in most situations.

Bears

Black and grizzly bears prey on livestock. Black bears usually kill by biting the neck or by slapping the victim. Torn, mauled, and mutilated carcasses are characteristic of bear attacks. Often, the bear will eat the udders of female prey, possibly to obtain milk. The victim usually is opened ventrally and the heart and liver are consumed (Bowns and Wade 1980). The intestines are often spread out around the kill site, and the animal may be partially skinned while the carcass is fed upon. Smaller livestock such as sheep and goats may be consumed almost entirely, and only the rumen, skin, and large bones left. Feces are generally found within the kill area, and a bedding site is often found nearby. Bears use their feet while feeding so they do not slide the prey around as do coyotes. If the kill is made in the open, it may be moved to a more secluded spot.

The grizzly has a feeding and killing pattern similar to that of the black bear. Murie (1948) found that most cattle are killed by a bite through the back of the neck. Large prey often have claw marks on the flanks or hams. The prey's back is sometimes broken in front of the hips where the bear simply crushed it down. Young calves are occasionally bitten through the forehead.

The presence of bears has stampeded range sheep, resulting in death from suffocation or from falls over cliffs. A marauding bear searching for food may also play havoc with garbage cans, cabins, camp sites, and apiaries (Maehr 1983).

Black bear damage to trees can be recognized by the large vertical incisor and claw marks on the sapwood and ragged strips of hanging bark. Pole-size trees to small saw timber are preferred. Most bark damage occurs during May, June, and July (Packham 1970). After the bark is pulled away, bears will scrape off the cambium layer of the tree with their incisor teeth, leaving vertical tooth marks (Murie 1954).

The bear track resembles that of a human, but has distinctive claw marks. The little inside toes often leave no marks in dust or shallow mud so the print appears to be four-toed (Murie 1954).

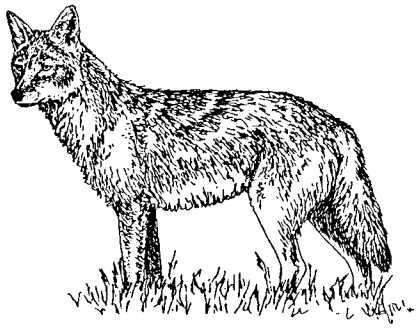
Bobcats and Lynx

These related species occasionally prey on sheep, goats, deer, and pronghorns; however, they more commonly kill smaller animals such as porcupines, poultry, rabbits, rodents, birds, and house cats. Bobcats characteristically kill adult deer by leaping on their back or shoulders, usually when the victim is lying down, and biting them on the trachea. The jugular vein may be punctured, but the victims usually die of suffocation and shock. Bowns (1976)

reported that a lamb killed by a bobcat had hemorrhages produced by claws on both sides of the carcass, indicating that the bobcat had held the lamb with its claws while biting the neck. Small fawns, lambs, and other small prey are often killed by a bite through the top of the neck or head (Young 1958). The hindquarters of deer or sheep are usually preferred by bobcats, although the shoulder and neck region or the flank are sometimes eaten first. The rumen is often untouched. Poultry are usually killed by biting the head and neck (Young 1958); the heads are usually eaten. Also, both species reportedly prey on bird eggs.

Bobcat and lynx droppings are similar; in areas inhabited by both species, the tracks will help determine the responsible animal. The lynx has larger feet with much more hair and the toes tend to spread more than they do on the more compact bobcat tracks.

Feline predators usually attempt to cover their kills with litter (Cook et al. 1971). Bobcats reach out 12 to 14 inches (30 to 35 cm) in scratching litter, compared to a 35-inch (90-cm) reach of a mountain lion (Young 1958). The distance between the canine teeth marks will also help distinguish a lion kill from that of a bobcat—1 1/2 inches (3.8 cm) for a lion versus 3/4 to 1 inch (1.9 to 2.5 cm) for a bobcat (Wade and Bowns 1982).



Coyotes, Wolves, and Dogs

These predators prey on animals ranging from big game and livestock to rodents, wild birds, and poultry. Coyotes are the most common and most serious predator of livestock in the western United States (Wade and Bowns 1982) and are rapidly becoming a problem throughout the east.

Coyotes normally kill livestock with a bite in the throat, but they infrequently pull the animal down by attacking the side, hindquarters, and udder. The rumen and intestines may be removed and dragged away from the carcass. On small lambs, the upper canine teeth may penetrate the top of the neck or the skull. Calf predation by coyotes is most common when calves are young. Calves that are attacked, but not killed, exhibit wounds in the flank, hindquarters, or front shoulders; often their tails are chewed off near the top. Deer carcasses are frequently completely dismembered and eaten (Bowns 1976).

Complaints of pets being killed by coyotes have increased with urbanization (Howell 1982). Also, the increase in the number of reported human attacks has created additional concern for urban dwellers. Avocado producers using drip irrigation systems report that coyotes chew holes in plastic pipe and disrupt irrigation (Cummings 1973). Coyotes damage watermelons by biting holes through the melons and eating the centers out; raccoons, on the other hand, make small holes in the melons and scoop the pulp out with their front paws. Coyotes will also damage other fruit crops.

Wolves prey on larger ungulates such as caribou, moose, elk, and cattle. Wolves usually bring down these animals by cutting or damaging the muscles and ligaments in the back legs or by seizing the victim in the flanks. Slash marks made by the canine teeth may be found on the rear legs and flanks. The downed animals usually are disembowelled.

Domestic dogs can be a serious problem to livestock, especially to sheep pastured near cities and suburbs. Dogs often attack the hindquarters, flanks, and head of livestock. They rarely kill as effectively as coyotes (Green et al. 1994). Normally, little flesh is consumed. Dogs are likely to wound the animal in the neck and front shoulders; the ears often are badly torn. Attacking dogs often severely mutilate the victim (Bowns and Wade 1980).

Coyote and dog tracks are similar but distinguishable. Dog tracks are round with the toes spread apart. Toenail marks are usually visible on all toes (Dorsett 1987). Coyote tracks are more rectangular and the toes are closer together. If any toenail marks show, they are usually of the middle toes. Also, coyote tracks appear in a straight line whereas those of a dog are staggered.

Foxes

Gray and red foxes feed primarily on rabbits, hares, small rodents, poultry, birds, and insects. They also consume fruits. The gray fox eats fish, a prey seldom eaten by the red fox. Gray and especially red foxes kill young livestock, although poultry is their more common domestic prey. Foxes usually attack the throat of lambs and birds, but kill some by multiple bites to the neck and back (Wade and Bowns 1982). Normally, foxes taking fowl leave behind only a few drops of blood and feathers and carry the prey away from the kill location, often to a den. Eggs are usually opened enough to be licked out. The shells are left beside the nest and are rarely removed to the den, even though fox dens are noted for containing the remains of their prey, particularly the wings of birds.

Einarsen (1956) noted that the breast and legs of birds killed by foxes are eaten first and the other appendages are scattered about. The toes of the victims are usually drawn up in a curled position because of tendons pulled when the fox strips meat from the leg bone. Smaller bones are likely to be sheared off. The remains are often partially buried.

Like other wild canids, foxes will return to established denning areas year after year. They dig dens in wooded areas or open plains. Hollow logs are also used. Dens may be identified by the small doglike tracks or by fox hairs clinging to the entrance. The gray fox is the only fox that readily climbs trees, sometimes denning in a hollow cavity.

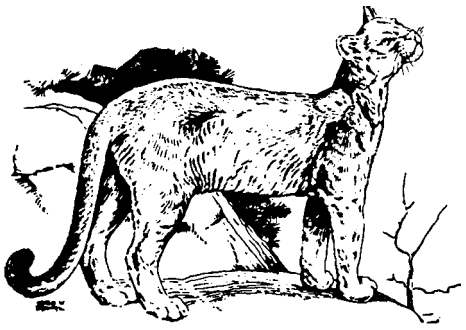
Hogs

Problems associated with feral or wild hogs have increased across the southern United States. Rooting and wallowing by wild hogs can damage agricultural crops and timber and also damage farm ponds and irrigation dikes (Barrett 1994). Wild hogs also feed on young sheep and goats in certain parts of the United States. The losses are difficult to determine at times because almost the entire carcass is either eaten or carried off and the only evidence may be tracks and blood where feeding occurred (Wade and Bowns 1982).

Tracks of adult hogs resemble those made by a 200-pound (90-kg) calf. In soft ground dewclaws will show on adult hog tracks (Barrett 1994).

Mountain Lions

Often called cougar or puma, this large feline preys on deer, elk, and domestic stock, particularly horses, sheep, goats, and cattle. It also eats rodents and other small mammals, when available. In one situation, according to Young (1933), a lone lion attacked a herd of ewes and killed 192 in one night. However, 5 to 10 sheep killed in a single night is more typical (Shaw 1983).



Mountain lions, having relatively short, powerful jaws, kill with bites inflicted from above, often severing the vertebral column and breaking the neck. They also kill by biting through the skull (Bowns 1976). Lions usually feed first on the front quarters and neck region of their prey. The stomach is generally untouched. The large leg bones may be crushed and the ribs broken. Many times, after a lion has made a kill, the prey is dragged or carried into bushy areas and covered with litter. A lion might return to feed on a kill for three or four nights. They normally uncover the kill at each feeding and move it from 11 to 27 yards (10 to 25 m) to recover it. After the last feeding the remains may be left uncovered, and a search of the area might reveal previous burial sites (Shaw 1983).

Adult lion tracks are approximately 4 inches (10 cm) in length and 4 1/4 inches (11 cm) in width; they have four well-defined impressions of the toes at the front, roughly in a semicircle. Lions have retractable claws; therefore, no claw prints will be evident. The untrained observer sometimes confuses large dog tracks with those of the lion; however, dog tracks normally show distinctive claw marks, are less round than lion tracks, and have distinctly different rear pad marks.

Opossums

Opossums are omnivorous and occasionally eat fish, crustaceans, insects, mushrooms, fruits, vegetables, eggs, and carrion. They will also raid poultry houses. The opossum usually kills one chicken at a time, often mauling the victim (Burkholder 1955). Eggs will be mashed and messy, the shells often chewed into small pieces and left in the nest. Opossums usually begin feeding on poultry at the cloacal opening. Young poultry or game birds are consumed entirely and only a few wet feathers left.

Raccoons

Raccoons eat mice, small birds, snakes, frogs, insects, crawfish, grass, berries, acorns, corn, melons — the list is almost endless. Garbage cans and dumps can be a major source of food in urban areas. Field crops or gardens near wooded areas may suffer severe damage from raccoons. Ripening corn is frequently eaten and much is wasted (Conover 1987). They raid nesting cavities of birds (Lacki et al. 1987). They will on occasion kill small lambs, usually by chewing the nose.

Occasionally, raccoons enter poultry houses and take several birds in one night. The breast and crop can be torn and chewed, and the entrails sometimes are eaten. There may be bits of flesh near water. Eggs may be removed from poultry or game bird nests and eaten away from the nest. Rearden (1951) found that eggshells were located within 28 feet (9 m) of the nest.

The raccoon leaves a distinctive five-toed track that resembles a small human hand print. Tracks are usually paired, the left hind foot beside the right forefoot (Murie 1954). Raccoon and opossum tracks can be difficult to distinguish in soft sand where toes do not show.

Skunks

Insects, particularly grasshoppers, beetles, and crickets, make up a large portion of the skunk's diet. Skunks usually dig small cone-shaped holes in lawns, golf courses, and meadows in search of beetle larvae. A common complaint of objectionable odor occurs

when skunks take up residence under buildings. Skunks may depredate beehives.

Skunks kill few adult birds, but are serious nest robbers (Einarsen 1956). Eggs are usually opened at one end; the edges are crushed as the skunk punches its nose into the hole to lick out the contents (Einarsen 1956, Davis 1959). The eggs may appear to have been hatched, except for the edges. When in a more advanced stage of incubation, eggs are likely to be chewed in small pieces. Eggs may be removed from the nest, but rarely more than 3 feet (1 m) away.

Most rabbit, chicken, and pheasant carcasses found at skunk dens are carrion that have been dragged to the den sites (Crabb 1948). When skunks kill poultry, they generally kill only one or two birds and maul them considerably. Crabb (1941) observed that spotted skunks help control rats and mice in grain storage buildings. They kill these rodents by biting and chewing the head and foreparts; the carcasses are not eaten.

Inhabited dens can be recognized by fresh droppings containing undigested insect parts near the mound or hole. Hair and rub marks also may be present. Dens usually have a characteristic skunk odor, although the odor may not be strong.

Weasels and Mink

Weasels and mink have similar feeding behaviors, killing prey by biting through the skull, upper neck, or jugular vein (Cahalane 1961). When they raid poultry houses at night, they often kill many birds, eating only the heads of the victims. Predation by rats usually differs in that portions of the body are eaten and carcasses are dragged into holes or concealed places.

Errington (1943) noted that mink, while eating large muskrats, make an opening at the back or side of the neck. As the mink eats away flesh and pieces of the adjacent hide, the ribs, head, and hindquarters are pulled out through the same hole and the animal is skinned. McCracken and Van Cleve (1947) noted similar feeding behavior by weasels eating small rodents.

Teer (1964) observed that blue-winged teal eggs destroyed by weasels were broken at the ends and had openings 1/2 to 3/4 inch (1.5 to 2.0 cm) in diameter. Close inspection of shell remains frequently will disclose finely chewed edges and tiny tooth marks (Rearden 1951).

Weasels den in the ground (for example, in a mole or pocket gopher burrow), under a barn, in a pile of stored hay, or under rocks. Mink dig dens approximately 4 inches (10 cm) in diameter into banks. Mink also use muskrat burrows, holes in logs and stumps, and other natural shelters.

Domestic Cats

Domestic cats rarely prey on anything larger than ducks, pheasants, rabbits, or quail. Einarsen (1956) noted the messy feeding behavior of these animals. Portions of their prey are often strewn over several square yards (m) in open areas. The meaty portions of large birds are consumed entirely, leaving loose skin with feathers attached. Small birds are generally consumed and only the wings and scattered feathers remain. Cats usually leave tooth marks on every exposed bone of their prey. Nesting birds are particularly vulnerable to cat predation. In areas managed for game birds or waterfowl production, vagrant cat control is almost a necessity. Unlike their native cousins, domestic cats are observed readily in the daytime, although feral cats are often extremely wary.

Acknowledgments

This chapter was adapted with permission from R. A. Dolbeer, N. R. Holler, and D. W. Hawthorne. 1994. *Identification and Control of Wildlife Damage.* T. A. Bookhout, ed. Research and management techniques for wildlife and habitats. The Wildlife Society, Bethesda, Maryland. 1994.

Literature Cited

Alsager, D. E. 1977. Impact of pocket gophers (*Thomomys talpoides*) on the quantitative productivity of rangeland vegetation in southern Alberta: a damage assessment tool. Pages 47-57 *in* W. B. Jackson and R. E. Marsh, eds. Vertebr. Pest Control and Manage. Materials: ASTM STP 625. Philadelphia.

Austin, D. D., and P. J. Urness. 1989. Evaluating production losses from mule deer depredation in apple orchards. Wildl. Soc. Bull. 17:161-165.

Arner, D. H., and J. S. Dubose. 1982. The impact of the beaver on the environment and economics in the southeastern United States. Trans. Int. Congr. Game Biol. 14:241-247.

Baker, R. O., R. M. Timm, and G. R. Bodman. 1994. Rodent-proof construction and exclusion methods. Pages B137-B150 *in* S. E. Hygnstrom, R. M. Timm, and G. E. Larson, eds. Prevention and control of wildlife damage. Univ. Nebraska Coop. Ext. Lincoln.

Barrett, R. H. 1994. Wild pigs. Pages D65-D70 *in* S. E. Hygnstrom, R. M. Timm, and G. E. Larson, eds. Prevention and control of wildlife damage. Univ. Nebraska Coop. Ext. Lincoln.

Beier, P., and R. H. Barrett. 1987. Beaver habitat use and impact in Truckee River basin, California. J. Wildl. Manage. 51:794-799.

Besser, J. F. 1986. A guide to aid growers in reducing bird damage to US agricultural crops. Denver Wildl. Res. Cent. Bird Damage Res. Rep. No. 377. 91pp.

Besser, J. F., and D. J. Brady. 1986. Bird damage to ripening field corn increases in the United States from 1971 to 1981. US Fish Wildl. Serv., Fish and Wildl. Leafl. 7. Washington, DC. 6pp.

Besser, J. F., J. W. DeGrazio and J. L. Guarino. 1968. Costs of wintering starlings and red-winged blackbirds at feedlots. J. Wildl. Manage. 32:179-180

Black, H. C., E. J. Dimock II, J. Evans, and J. A. Rochelle. 1979. Animal damage to coniferous plantations in Oregon and Washington. Part I. A survey, 1963-75. Oregon State Univ., For. Res. Lab., Corvallis Res. Bull. 25. 44 pp.

Blokpoel, H., and G. D. Tessier. 1984. Overhead wires and monofilament lines exclude ring-billed gulls from public places. Wildl. Soc. Bull. 12:55-58.

Bollengier, R. M., Jr. 1994. Woodchucks. Pages B183-B187*in* S. E. Hygnstrom, R. M. Timm, and G. E. Larson, eds. Prevention and control of wildlife damage. Univ. Nebraska Coop. Ext. Lincoln.

Borrecco, J. E., and R. J. Anderson. 1980. Mountain beaver problems in the forests of California, Oregon, and Washington. Proc. Vertebr. Pest Conf. 9:135-142.

Bowns, J. E. 1976. Field criteria for predator damage assessment. Utah Sci. 37(1):26-30.

Bowns, J. E., and D. A. Wade. 1980. Physical evidence of carnivore depredation. Texas Agric. Ext. Serv. College Stn. (35mm slide series and script).

Brodie, J. D., H. C. Black, E. J. Dimock II, J. Evans, C. Kao, and J. A. Rochelle. 1979. Animal damage to coniferous plantations in Oregon and Washington — Part II. An economic evaluation. Corvallis Res. Bull., For. Res. Lab., Oregon State Univ. No. 26. 22pp.

Bullock, J. F., and D. H. Arner. 1985. Beaver damage to nonimpounded timber in Mississippi. Southern J. Appl. For. 9:137-140.

Burkholder, B. L. 1955. Control of small predators. US Fish Wildl. Serv. Circ. 33. 8pp.

Byers, R. E. 1984. Control and management of vertebrate pests in deciduous orchards of the eastern United States. Hort. Rev. 6:253-285.

Cahalane, V. H. 1961. Mammals of North America. Macmillan Co., New York. 682 pp.

Capp, J. C. 1976. Increasing pocket gopher problems in reforestation. Proc. Vertebr. Pest Conf. 7:221-228.

Carr, A. 1982. Armadillo dilemma. Anim. Kingdom 85(5):40-43.

Case, R. M., and B. A. Jasch. 1994. Pocket gophers. Pages B117-B129 *in* S. E. Hygnstrom, R. M. Timm, and G. E. Larson, eds. Prevention and control of wildlife damage. Univ. Nebraska Coop. Ext. Lincoln.

Clark, J. 1984. Vole control in field crops. Proc. Vertebr. Pest Conf. 11:5-6.

Clark, W. R., and R. E. Young. 1986. Crop damage by small mammals in no-till cornfields. J. Soil Water Conserv. 41:338-341.

Conner, W. H., and J. R. Toliver. 1987. The problem of planting Louisiana swamplands when nutria (*Myocastor coypus*) are present. Proc. East. Wildl. Damage Control Conf. 3:42-49.

Connelly, N. A., D. J. Decker, and S. Wear. 1987. Public tolerance of deer in a suburban environment: implications for management and control. Proc. East. Wildl. Damage Control Conf. 3:207-218.

Conover, M. R. 1987. Reducing raccoon and bird damage to small corn plots. Wildl. Soc. Bull. 15:268-272.

Conover, M. R. 1988. Effect of grazing by Canada geese on the winter growth of rye. J. Wildl. Manage. 52:76-80.

Conover, M. R., and G. G. Chasko. 1985. Nuisance Canada goose problems in the eastern United States. Wildl. Soc. Bull. 13:228-233.

Cook, R. S., M. White, D. O. Trainer, and W. C. Glazener. 1971. Mortality of young white-tailed deer fawns in south Texas. J. Wildl. Manage. 35:47-56.

Cowardin, L. M., D. S. Gilmer, and C. W. Shaiffer. 1985. Mallard recruitment in the agricultural environment of North Dakota. Wildl. Monogr. 92:1-37.

Crabb, W. D. 1941. Civits are rat killers. Iowa Farm Sci. Rep. 2(1):12-13.

Crabb, W. D. 1948. The ecology and management of the prairie spotted skunk in Iowa. Ecol. Monogr. 18:201-232.

Craven, S. R. 1994. Cottontail rabbits. Pages D75-D80 *in* S. E. Hygnstrom, R. M. Timm, and G. E. Larson, eds. Prevention and control of wildlife damage. Univ. Nebraska Coop. Ext. Lincoln.

Craven, S. R. 1983*b*. New directions in deer damage management in Wisconsin. Proc. East. Wildl. Damage Control Conf. 1:65-67.

Crouch, G. L. 1976. Deer and reforestation in the Pacific northwest. Proc. Vertebr. Pest Conf. 7:298-301.

Crouch, G. L. 1986. Pocket gopher damage to conifers in western forests: a historical and current perspective on the problem and its control. Proc. Vertebr. Pest Conf. 12:196-198.

Cummings, M. W. 1973. Rodents and drip irrigation. Proc. Drip Irrigation Semin., San Diego, Calif. 4:25-30.

Cummings, M. W., and R. E. Marsh. 1978. Vertebrate pests of citrus. Page 237-273 *in* W. E. Reuther, E. C. Calavan, and G. E. Garman, eds. The Citrus Industry. Vol. IV. Div. Agric. Sci., Univ. California, Davis.

Davidson, W. R., and V. F. Nettles. 1988. Field manual of wildlife diseases in the southeastern United States. Southeast. Coop. Wildl. Dis. Study, Univ. Georgia, Athens. 309 pp.

Davis, J. R. 1959. A preliminary progress report on nest predation as a limiting factor in wild turkey populations. Pages 138-145 *in* Proc. Natl. Wild Turkey Manage. Symp. Southeast. Sect. Wildl. Soc. 200 pp.

DeCalesta, D. S., and D. B. Schwendeman. 1978. Characterization of deer damage to soybean plants. Wildl. Soc. Bull. 6:250-253.

DeGrazio, J. W., J. F. Besser, J. L. Guarino, C. M. Loveless, and J. L. Oldemeyer. 1969. A method for appraising blackbird damage to corn. J. Wildl. Manage. 33:988-994.

Dolbeer, R. A. 1975. Comparison of two methods for estimating bird damage to sunflowers. J. Wildl. Manage. 39:802-806.

Dolbeer, R. A. 1981. Cost-benefit determination of blackbird damage control for cornfields. Wildl. Soc. Bull. 9:43-50.

Dolbeer, R. A. 1994. Blackbirds. Pages E25-E32 *in* S. E. Hygnstrom, R. M. Timm, and G. E. Larson, eds. Prevention and control of wildlife damage. Univ. Nebraska Coop. Ext. Lincoln.

Dolbeer, R. A., W. R. Holler, and D. W. Hawthorne. 1994. Identification and control of wildlife damage. Pages 474-506 *in* T. A. Bookhout, ed. Research and management techniques for wildlife and habitats. The Wildlife Society, Bethesda, Maryland.

Dolbeer, R. A., and R. A. Stehn. 1983. Population status of blackbirds and starlings in North America, 1966-81. Proc. East. Wildl. Damage Control Conf. 1:51-61.

Dolbeer, R. A., R. A. Stickley, Jr., and P. P. Woronecki. 1979. Starling (*Sturnus vulgaris*) damage to sprouting wheat in Tennessee and Kentucky, USA. Prot. Ecol. 1:159-169.

Dorsett, J. 1987. Trapping coyotes. Leafl. 1908. Texas An. Damage Control Serv. San Antonio. 4pp.

Eadie, W. R. 1954. Animal control in field, farm and forest. The Macmillan Co., New York. 257pp.

Einarsen, A. S. 1956. Determination of some predatory species by field signs. Oregon State Univ. Monogr. Stud. in Zool. No. 10. 34pp.

Errington, P. L. 1943. An analysis of mink predation upon muskrat in north-central United States. Iowa State College. Agric. Exp. Stn. Res. Bull. 320:794-924.

Evans, D., J. L. Byford, and R. H. Wainberg. 1983. A characterization of woodpecker damage to houses in east Tennessee. Proc. East. Wildl. Damage Control Conf. 1:325-330.

Evans, J. 1987*a*. Mountain beaver damage and management. Pages 73-74 *in* D. M. Baumgartner, R. L. Mahoney, J. Evans, J. Caslick and D. W. Brewer, Co-chair. An. Damage Manage. in Pacific Northwest For. Coop. Ext. Serv., Washington State Univ., Fullman.

Evans, J. 1987*b*. The porcupine in the Pacific northwest. Pages 75-78 *in* D. M. Baumgartner, R. L. Mahoney, J. Evans, J. Caslick, and D. W. Brewer, Co-chair. An. Damage Manage. in Pacific Northwest For. Coop. Ext. Serv., Washington State Univ., Fullman.

Fagerstone, K. A. 1981. A review of prairie dog diet and its variability among animals and colonies. Proc. Great Plains Wildl. Damage Control Workshop. Univ. Nebraska, Lincoln. 5:178-184.

Ferguson, W. L. 1980. Rodenticide use in apple orchards. Proc. East. Pine and Meadow Vole Symp. 4:2-8.

Foster, M. A., and J. Stubbendieck. 1980. Effects of the Plains pocket gopher (*Geomys bursarius*) on rangeland. J. Range Manage. 33:74-78.

Frantz, S. C. 1986. Batproofing structures with birdnetting checkvalves. Proc. Vertebr. Pest Conf. 12:260-268.

Glahn, J. F., D. J. Twedt, and D. L. Otis. 1983. Estimating feed loss from starling use of livestock feed troughs. Wildl. Soc. Bull. 11:366-372.

Glahn, J. F., and W. Stone. 1984. Effects of starling excrement in the food of cattle and pigs. Anim. Prod. 38:439-446.

Green, J. S., F. R. Henderson, and M. D. Collinge. 1994. Coyotes. Pages C51-C76 *in* S. E. Hygnstrom, R. M. Timm, and G. E. Larson, eds. Prevention and control of wildlife damage. Univ. Nebraska Coop. Ext. Lincoln.

Greenhall, A. M. 1982. House bat management. US Dep. Inter. Fish Wildl. Serv. Resour. Publ. No. 143. 33 pp.

Hadidian, J., D. Manski, V. Flyger, C. Cox, and G. Hodge. 1987. Urban gray squirrel damage and population management: a case history. Proc. East. Wildl. Damage Control Conf. 3:219-227.

Hamilton, J. C., R. J. Johnson, R. M. Case, M. W. Riley, and W. W. Stroup. 1987. Fox squirrels cause power outages: an urban wildlife problem. Proc. East. Wildl. Damage Control Conf., 3:228.

Harder, J. D. 1970. Evaluating winter deer use of orchards in western Colorado. Trans. North Am. Wildl. Resour. Conf. 35:35-47.

Hawthorne, D. W. 1994. Cotton rats. Pages B97-B99 *in* S. E. Hygnstrom, R. M. Timm, and G. E. Larson, eds. Prevention and control of wildlife damage.
Univ. Nebraska Coop. Ext. Lincoln.

Henderson, F. R. 1994. Moles. Pages D51-D58 *in* S. E. Hygnstrom, R. M. Timm, and G. E. Larson, eds. Prevention and control of wildlife damage. Univ. Nebraska Coop. Ext. Lincoln.

Hooven, E. F. 1959. Dusky-footed woodrat in young Douglas fir. Oregon For. Res. Cent., Res. Note 41, Corvallis. 24pp.

Hothem, R. L., R. W. DeHaven, and S. D. Fairaizl. 1988. Bird damage to sunflower in North Dakota, South Dakota, and Minnesota, 1979-1981. US Dep. Inter. Fish Wildl. Tech. Rep. 15. 11 pp.

Howard, V. W., Jr. 1994. Kangaroo rats. Pages B101-B104 *in* S. E. Hygnstrom, R. M. Timm, and G. E. Larson, eds. Prevention and control of wildlife damage. Univ. Nebraska Coop. Ext. Lincoln.

Howell, R. G. 1982. The urban coyote problem in Los Angeles County. Proc. Vertebr. Pest Conf. 10:55-61.

Humphrey, S. R. 1974. Zoogeography of the nine-banded armadillo (*Dasypus novemcinctus*) in the United States. BioScience 24:457-462.

Hygnstrom, S. E., and S. R. Craven. 1994. Hawks and owls. Pages E53-E61 *in* S. E. Hygnstrom, R. M. Timm, and G. E. Larson, eds. Prevention and control of wildlife damage. Univ. Nebraska Coop. Ext. Lincoln.

Hygnstrom, S. E., and D. R. Virchow. 1994. Prairie dogs. Pages B85-96 *in* S. E. Hygnstrom, R. M. Timm, and G. E. Larson, eds. Prevention and control of wildlife damage. Univ. Nebraska Coop. Ext. Lincoln.

Hygnstrom, S. E., and S. R. Craven. 1988. Electric fences and commercial repellents for reducing deer damage in cornfields. Wildl. Soc. Bull. 16:291-296.

Jackson, J. J. 1994. Tree squirrels. Pages B171-B175 *in* S. E. Hygnstrom, R. M. Timm, and G. E. Larson, eds. Prevention and control of wildlife damage. Univ. Nebraska Coop. Ext. Lincoln.

Jackson, W. B. 1987. Current management strategies for commensal rodents. Pages 495-512 *in* H. H. Genoways, ed. Current mammalogy. Vol. 1. Plenum Press, New York. 519 pp.

Johnson, R. J. 1986. Wildlife damage in conservation tillage agriculture: a new challenge. Proc. Vertebr. Pest Conf. 12:127-132.

Kahl, R. B., and F. B. Samson. 1984. Factors affecting yield of winter wheat grazed by geese. Wildl. Soc. Bull. 12:256-262.

Kincaid, S. P. 1975. Bats, biology, and control. Proc. Great Plains Wildl. Damage Control Workshop 2:187-194.

Knight, J. E. 1994. Jackrabbits. Pages D81-D85 *in* S. E. Hygnstrom, R. M. Timm, and G. E. Larson, eds. Prevention and control of wildlife damage. Univ. Nebraska Coop. Ext. Lincoln.

Knittle, C. E., and R. D. Porter. 1988. Waterfowl damage and control methods in ripening grain: an overview. US Fish Wildl. Tech. Rep. 14. 17pp.

Lacki, M. J., S. P. George, and P. J. Viscosi. 1987. Evaluation of site variables affecting nest box use by wood ducks. Wildl. Soc. Bull. 15:196-200.

Larsen, K. H., and J. H. Dietrich. 1970. Reduction of raven population on lambing grounds with DRC-1339. J. Wildl. Manage. 34:200-204.

Lawrence. W. H., N. B. Kverno, and H. D. Hartwell. 1961. Guide to wildlife feeding injuries on conifers in the Pacific northwest. West. For. Conserv. Assoc., Portland, Oregon. 44pp.

LeBlanc, D. A. 1994. Nutria. Pages B71-B80 *in* S. E. Hygnstrom, R. M. Timm, and G. E. Larson, eds. Prevention and control of wildlife damage. Univ. Nebraska Coop. Ext. Lincoln.

Lefebvre, L. W., C. R. Ingram, and M. C. Yang. 1978. Assessment of rat damage to Florida sugarcane in 1975. Proc. Amer. Soc. Sugar Cane Tech. 7:75-80.

Lindzey, F. G. 1994. Badgers. Pages C1-C3*in* S. E. Hygnstrom, R. M. Timm, and G. E. Larson, eds. Prevention and control of wildlife damage. Univ. Nebraska Coop. Ext. Lincoln.

Luce, D. G., R. M. Case, and J. L. Stubbendieck. 1981. Damage to alfalfa fields by Plains pocket gophers. J. Wildl. Manage. 45:258-260.

Maehr, D. S. 1983. Black bear depredation on bee yards in Florida. Proc. East. Wildl. Damage Control Conf. 1:133-135.

Marsh, R. E. 1994. Roof rats. Pages B125-B132 *in* S. E. Hygnstrom, R. M. Timm, and G. E. Larson, eds. Prevention and control of wildlife damage. Univ. Nebraska Coop. Ext. Lincoln.

Marsh, R. E. 1985. Competition of rodents and other small mammals with livestock in the United States. Pages 485-508 *in* S. M. Gaafar, W. E. Howard, and R. E. Marsh, eds. Parasites, pests and predators. Elsevier Science Publ. B. V., Amsterdam, The Netherlands.

Marsh, R. E. 1986. Ground squirrel control strategies in Californian agriculture. Pages 261-276 *in* C. G. J. Richards and T. Y. Ku, eds. Control of mammal pests. Taylor and Francis, Inc., Philadelphia.

Marsh, R. E., and W. E. Howard. 1990. Vertebrate pests. Pages 791-861 *in* A. Mallis, ed. Handbook of pest control, 7th ed. Franzak and Foster Co., Cleveland, Ohio.

McCracken, H., and H. Van Cleve. 1947. Trapping: the craft and science of catching fur-bearing animals. Barnes Co., New York. 196pp.

McDonough, W. T. 1974. Revegetation of gopher mounds on aspen range in Utah. Great Basin Nat. 34:267-275.

Meehan, A. P. 1984. Rats and mice. Their biology and control. Rentokil Ltd., W. Sussex, England. 383pp.

Merritt, R. L. 1990. Bird strikes to US Air Force aircraft, 1988-89. Bird Strike Committee Europe 20:511-518.

Miller, J. E. 1994. Muskrats. Pages B61-B69 *in* S. E. Hygnstrom, R. M. Timm, and G. E. Larson, eds. Prevention and control of wildlife damage. Univ. Nebraska Coop. Ext. Lincoln.

Miller, J. E. 1987. Assessment of wildlife damage on southern forests. Pages 48-52 *in* J. G. Dickinson and D. E. Maughan, eds. Proc. Manage. South. For. Wildl. and Fish. Gen. Tech. Rep. SO-65., New Orleans, LA.

Murie, A. 1948. Cattle on grizzly bear range. J. Wildl. Manage. 12:57-72.

Murie, O. J. 1954. A field guide to animal tracks. Houghton Mifflin Co., Boston. 374pp.

National Agricultural Statistics Service (NASS). 1991. Sheep and goat predator loss. US Dep. Agric., Agric. Stat. Board. Washington, DC. 23 pp.

National Agricultural Statistics Service (NASS). 1992. Cattle and calves death loss. US Dep. Agric., Agric. Stat. Board Washington, DC 23 pp.

Nielsen, D. G., M. J. Dunlap, and K. V. Miller. 1982. Pre-rut rubbing by white-tailed bucks: nursery damage, social role, and management options. Wildl. Soc. Bull. 10:341-348.

O'Brien, J. M. 1994. Voles. Pages B177-B182 *in* S. E. Hygnstrom, R. M. Timm, and G. E. Larson, eds. Prevention and control of wildlife damage. Univ. Nebraska Coop. Ext. Lincoln.

O'Gara, B. W. 1978. Sheep depredation by golden eagles in Montana. Proc. Vertebr. Pest Conf. 8:206-213.

O'Gara, B. W. 1994. Eagles. Pages E41-E48 *in* S. E. Hygnstrom, R. M. Timm, and G. E. Larson, eds. Prevention and control of wildlife damage. Univ. Nebraska Coop. Ext. Lincoln.

Ostry, M. E., and T. H. Nicholls. 1976. How to identify and control sapsucker injury on trees. North Central For. Exp. Stn., St. Paul, Minnesota. 6pp.

Otis, D. L., N. R. Holler, P. W. Lefebvre, and D. F. Mott. 1983. Estimating bird damage to sprouting rice. Pages 76-89 *in* D. E. Kaukeinen, ed. Vertebr. Pest Control and Manage. Materials. ASTM STP 817. Philadelphia.

Packham, C. J. 1970. Forest animal damage in California. US Fish Wildl. Serv. Sacramento, California. 4pp.

Pauls, D. T. 1986. Protection with Vexar cylinders from damage by meadow voles of tree and shrub seedlings in northeastern Alberta. Proc. Vertebr. Pest Conf. 12:199-204.

Pearce J. 1947. Identifying injury by wildlife to trees and shrubs in northeastern forests. US Fish Wildl. Serv. Res. Rep. 13. 29pp.

Pearson, E. W. 1986. A literature review of livestock losses to predators in western US. US Fish and Wildl. Serv., Denver Wildl. Res. Cent., Denver, Colorado. Unpubl. Final Rep. 20pp.

Pearson, K., and C. G. Forshey 1978. Effects of pine vole damage on tree vigor and fruit yield in New York orchards. Hort Sci. 13:56-57.

Phillips, R. L., and F. S. Blom. 1988. Distribution and magnitude of eagle/livestock conflicts in the western United States. Proc. Vertebr. Pest Conf. 13:241-244.

Rearden, J. D. 1951. Identification of waterfowl nest predators. J. Wildl. Manage. 15:386-395.

Reynolds, H. G., and G. E. Glendening. 1949. Merriam kangaroo rat: a factor in mesquite propagation on southern Arizona rangelands. J. Range Manage. 2:193-197.

Richmond, M. E., C. G. Forshey, L. A. Mahaffy, and P. N. Miller. 1987. Effects of differential pine vole populations on growth and yield of McIntosh apple trees. Proc. East. Wildl. Damage Control Conf. 3:296-304.

Royall, W. C., Jr. 1969. Trapping house sparrows to protect experimental grain crops. US Fish Wildl. Serv. Leafl. No. 484, Washington, DC. 4pp.

Salmon, T. P., and W. P. Gorenzel. 1994. Woodrats. Pages B133-B136 *in* S. E. Hygnstrom, R. M. Timm, and G. E. Larson, eds. Prevention and control of wildlife damage. Univ. Nebraska Coop. Ext. Lincoln.

Salmon, T. P., and F. S. Conte. 1981. Control of bird damage at aquaculture facilities. US Dep. Inter., Univ. Calif. Coop. Extension Wildl. Manage. Leafl. No 475. 11pp.

Sargeant, A. B., S. H. Allen, and R. T. Eberhardt. 1984. Red fox predation on breeding ducks in midcontinent North America. Wildl. Monogr. 89:1-41.

Sargeant, A. B., and P. M. Arnold. 1984. Predator management for ducks on waterfowl production areas in the northern plains. Proc. Vertebr. Pest Conf. 11:161-167.

Sauer, W. C. 1977. Exclusion cylinders as a means of assessing losses of vegetation due to ground squirrel feeding. Pages 14-21 *in* W. B. Jackson and R. E. Marsh, eds. Vertebr. Pest Control and Manage. Materials. ASTM STP 625. Philadelphia.

Scott, J. D., and T. W. Townsend. 1985. Characteristics of deer damage to commercial tree industries of Ohio. Wildl. Soc. Bull. 13:135-143.

Seubert, J. L. 1984. Research on nonpredatory mammal damage control by the U.S. Fish and Wildlife Service. Pages 553-571 *in* A. C. Dubbock, ed. Organization and practice of vertebrate pest control. Imperial Chemical Industries PLC. Surrey, England.

Shaw, H. G. 1983. Mountain lion field guide. Spec. Rep. No. 9. Arizona Game and Fish Dep. Pheonix. 38pp.

Silver, J., and A. W. Moore. 1941. Mole control. US Fish Wildl. Serv. Conserv. Bull. 16. 17pp.

Solman, V. E. F. 1981. Birds and aviation. Environ. Conserv. 8(1):45-51.

Steenblik, J. W. 1983. Battling the birds. Air Line Pilot 52:18-23.

Stickley, A. R. Jr., and K. J. Andrews. 1989. Survey of Mississippi catfish farmers on means, effort, and costs to repel fish-eating birds from ponds. Proc. East. Wildl. Damage Control Conf. 4:105-108.

Stickley, A. R., Jr., D. L. Otis, and D. T. Palmer. 1979. Evaluation and results of a survey of blackbirds and mammal damage to mature field corn over a large (three-state) area. Pages 169-177 *in* J. R. Beck, ed. Vertebr. Pest Control and Manage. Materials, ASTM STP 680, Philadelphia.

Sugden, L. G., and D. W. Goerzen. 1979. Preliminary measurements of grain wasted by field-feeding mallards. Can. Wildl. Serv. Prog. Notes No. 104. 5pp.

Sullivan, T. P. 1978. Biological control of conifer seed damage by the deer mouse (*Peromyscus maniculatus*). Proc. Vertebr. Pest Control Conf. 8:237-250.

Sullivan, T. P., J. A. Krebs, and H. A. Kluge. 1987. Survey of mammal damage to tree fruit orchards in Okanagan Valley of British Columbia. Northwest Sci. 61:499-500.

Teer, J. G. 1964. Predation by long-tailed weasels on eggs of blue-winged teal. J. Wildl. Manage. 28:404-406.

Terrill, C. E. 1988. Predator losses climb nationwide. National Wool Grower. 78(9):32-34.

Tilghman, N. G. 1989. Impacts of white-tailed deer on forest regeneration in northwestern Pennsylvania. J. Wildl. Manage. 53:524-532.

Timm, R. M. 1994. Norway rats. Pages B105-B120 *in* S. E. Hygnstrom, R. M. Timm, and G. E. Larson, eds. Prevention and control of wildlife damage. Univ. Nebraska Coop. Ext. Lincoln.

Tobin, M. E., and R. A. Dolbeer. 1987. Status of Mesurol as a bird repellent for cherries and other fruit crops. Proc. East. Wildl. Damage Control Conf. 3:149-158.

Tobin, M. E., R. A. Dolbeer, and P. P. Woronecki. 1989. Damage to apples in the Mid-Hudson Valley of New York. Hort. Sci. 24:859.

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

Wade, D. A. 1982. Impacts, incidence and control of predation on livestock in the United States with particular reference to predation of coyotes. Counc. for Agric. Sci. and Tech., Spec. Publ. 10. 20pp.

Wade, D. A., and J. E. Bowns. 1982. Procedures for evaluating predation on livestock and wildlife. Bull. B-1429. Texas Agric. Extension Serv. College Stn. 42pp.

Weatherhead, P. J., S. Tinker, and H. Greenwood. 1982. Indirect assessment of avian damage to agriculture. J. Appl. Ecol. 19:773-782.

Weber, W. J. 1979. Health hazards from pigeons, starlings and English sparrows. Thomson Publ., Fresno, California. 138pp.

Weber, W. J. 1982. Disease transmitted by rats and mice. Thomson Publ. Fresno, California. 182pp.

White, S. B., R. A. Dolbeer, and T. A. Bookhout. 1985. Ecology, bioenergetics, and agricultural impacts of a winter-roosting population of blackbirds and starlings. Wildl. Monog. 93. 42pp.

Wick, W. Q., and A. S. Landforce. 1962. Mole and gopher control. Oregon State Univ. Coop. Ext. Bull. 804. 16pp.

Woodward, D. K. 1985. Beaver management in the southeastern United States: a review and update. Proc. East. Wildl. Damage Control Conf. 1:163-165.

Woronecki, P. P., R. A. Stehn, R. A. Dolbeer. 1980. Compensatory response of maturing corn kernels following simulated damage by birds. J. Appl. Ecol. 17:737-746.

Young, S. P. 1933. Hints on mountain lion trapping. Bur. of Biol. Surv. Leafl. No. 94. Washington, DC. 8pp.

Young, S. P. 1958. The bobcat of North America. Stackpole Co., Harrisburg, Pennsylvania, and the Wildl. Manage. Inst. Washington, DC. 193pp.

Editors

Scott E. Hygnstrom
Robert M. Timm
Gary E. Larson