DAMAGE IDENTIFICATION

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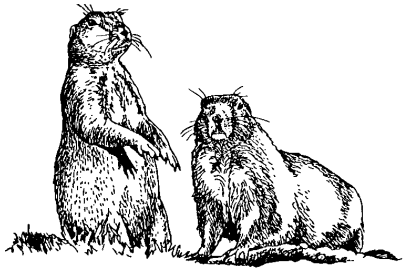
IDENTIFICATION AND ASSESSMENT OF WILDLIFE DAMAGE: AN OVERVIEW

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

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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).

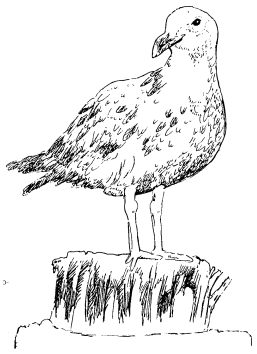
Unlike most mammals, which are secretive when causing damage, birds are often highly visible and their damage conspicuous. For this reason, subjective estimates often overestimate losses as much as tenfold (Weatherhead et al. 1982). Thus, objective estimates of bird damage to agricultural crops are important 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).

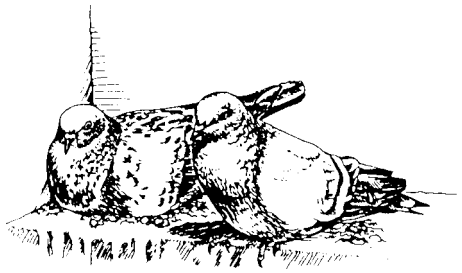
Blackbird damage to ripening corn, sunflower, and rice can be serious (Dolbeer 1994). Much of this damage is done in late summer during the milk or dough stage of seed development. The seed contents of corn are removed, leaving the pericarp or outer coat on the cob. Blackbird damage to sprouting rice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

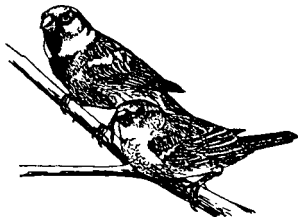
Starling depredations at feedlots in winter can cause substantial losses (Glahn et al. 1983, Besser et al. 1968). Although contamination of livestock feed by starling feces is often a concern of farmers, a study indicated this contamination did not interfere with food consumption or weight gain of cattle 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.

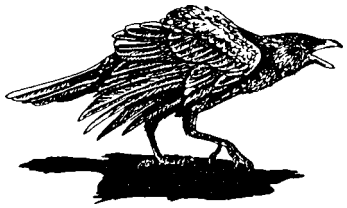
Pigeons and House Sparrows

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.

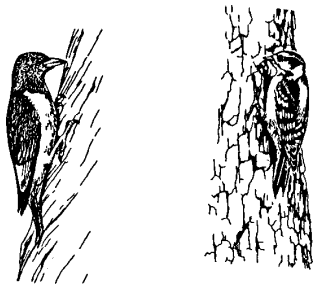
Golden Eagles

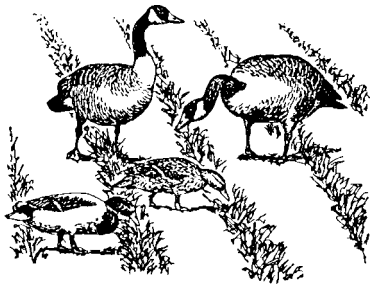
Golden eagles occasionally kill livestock, primarily lambs and kids on range. This predation can be locally severe in the sheep-producing areas from New Mexico to Montana (Phillips and Blom 1988).

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).

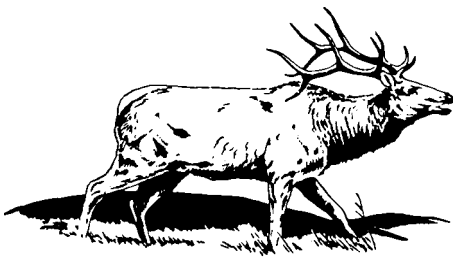
Ungulates (Deer, Elk, Moose)

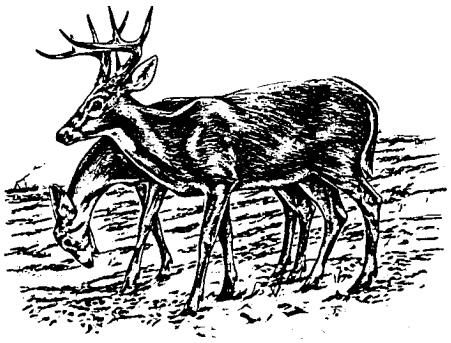
Damage Assessment

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

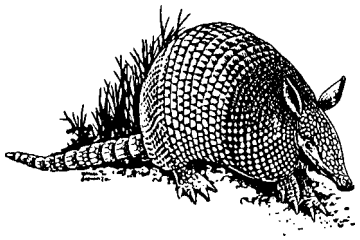
Most wild mammals are secretive and not easily observed; many are nocturnal. Often the investigator must rely on various signs, such as tracks, trails, tooth marks, scats, or burrows to determine the species doing the damage. Trapping may be necessary to make a positive identification of small rodents;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

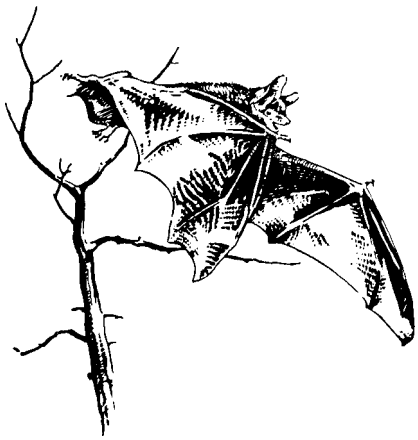
Armadillos

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.

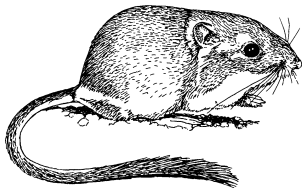
***Peromyscus* (Deer Mice, White-footed Mice)**

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

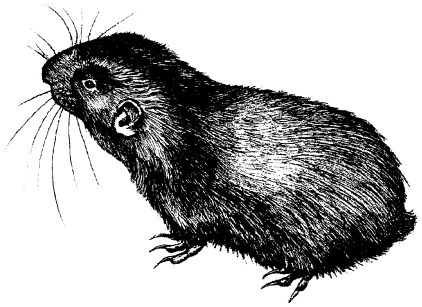
Voles (genus *Microtus*), also called meadow mice, field mice, and pine mice, cause extensive damage to forests, orchards, and ornamentals by gnawing bark and roots (Pearson and Forshey 1978, Byers 1984, Pauls 1986, Sullivan et al. 1987, O'Brien 1994). Tree or shrub damage usually occurs under snow or 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).

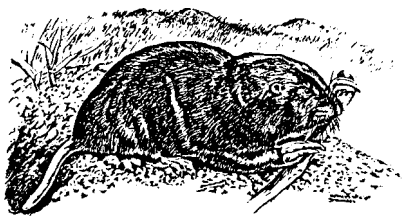
Nutria

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

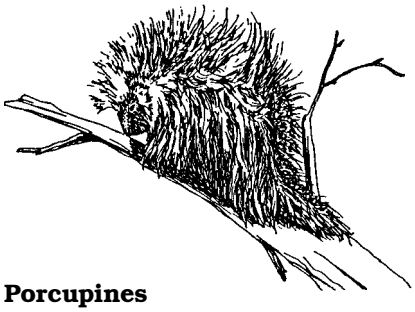
Pocket gophers cause substantial damage to agricultural crops, lawns, rangeland, and tree plantings. Gophers feed primarily on the underground portions of plants and trees. Damage often is undetected until a tree shows aboveground signs of stress; by then damage is frequently lethal (Cummings and Marsh 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.

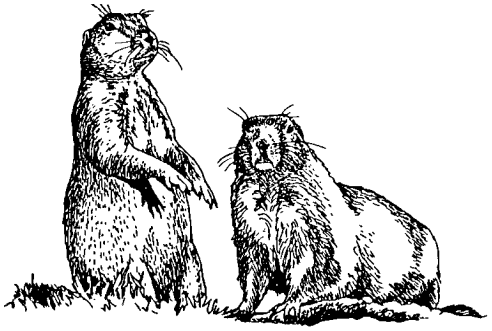


Porcupines

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.

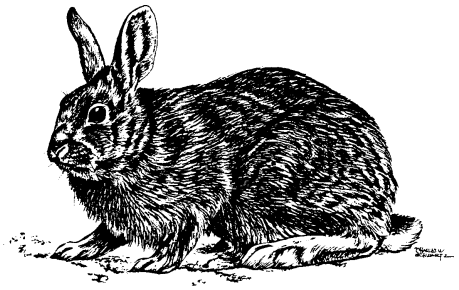
Prairie dog colonies are easily identified by the conical mounds around burrow entrances and by the presence of the easily observed animals.

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



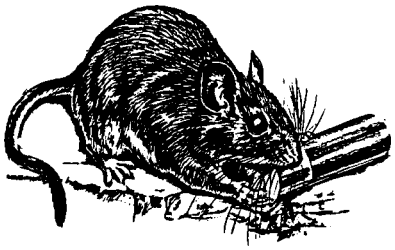
large fluctuations, and, at times of high density, damage to rangeland vegetation and competition with livestock can be severe.

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).

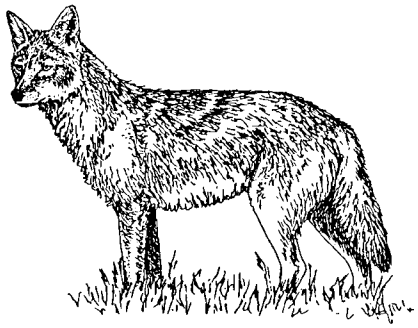
Bobcats and Lynx

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.

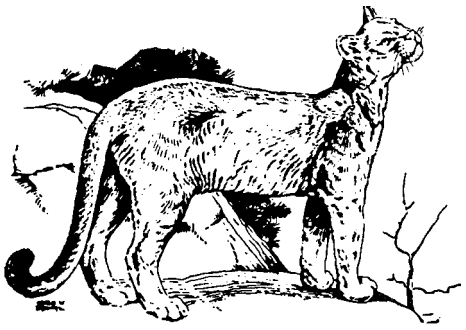
Hogs

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

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OBTAINING ASSISTANCE TO CONTROL WILDLIFE DAMAGE

Introduction

The Wildlife Society (TWS) policy statement for wildlife damage control (1992) states: "Prevention or control of wildlife damage . . . is an essential and responsible part of wildlife management." The role of wildlife damage control in our society is changing and so is public perception of it. This change is recognized among wildlife managers and researchers.

Efforts are under way to make the wildlife damage control profession more responsive to concerns of society. Formal petition for the establishment of a Wildlife Damage Working Group within TWS was made to the Wildlife Society Council on March 21, 1993 and the following day the council approved interim status for the working group.

Wildlife damage control professionals should be prepared to promptly supply the best information available to solve conflicts between people and wildlife. Often, the most urgently needed information is where to go for assistance when a problem arises.

This chapter provides options for obtaining assistance. It tells who does what to minimize conflicts between people and wild animals, and it gives suggestions for obtaining self-help information and/or reaching people who can provide onsite help.

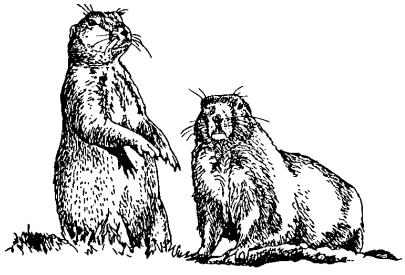
Background

Wildlife managers and agricultural specialists are often familiar with damage caused by wild animals to livestock, crops, and other types of private and public property. Conover and Decker (1991) surveyed wildlife managers and agricultural specialists throughout the United States and concluded that damage caused by wild animals was a major agricultural problem. Twenty-seven species were cited as causing the greatest problems. From a national perspective, deer reportedly caused the most damage, followed by elk, raccoons, beavers, blackbirds, and coyotes.

Damage by wild animals to ornamental plants, buildings, roads, and other structures can be serious. Some of the most costly problems are caused by house mice, Norway and roof rats, beavers, and deer (see chapters on these species in this handbook). Wild animals also cause nuisance problems, particularly in urban areas. Problems range from feces left on golf course greens by ducks and geese and garbage containers overturned by raccoons, to disturbing sounds made as small mammals move in attics and walls. Chapters in this handbook provide information about nuisance problems caused by bats, tree squirrels, raccoons, woodpeckers, ducks and geese, and other problem species.

Under some conditions wild animals are reservoirs of diseases, presenting a threat to other wildlife populations, to domestic animals, and to human health (See **Wildlife Diseases and Humans,** Friend 1987, Davidson and Nettles 1988). Also, public safety is at risk from automobile and aircraft collisions with wild animals (Dolbeer et al. 1989, Hansen 1983).

People usually enjoy having wild animals near their homes and most are willing to tolerate moderate damage from wildlife. Some people are able to control wildlife damage on their own. Others, before acting on their own, need information about the life histories of the animals causing problems, the legal status of the animals, and suggestions about controlling damage. Still others need professional, onsite help to solve wildlife damage problems. There are programs available to meet the needs of do-it-yourself wildlife managers and onsite assistance for people who need more help.



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

Obtaining Assistance

Table 1 shows whom to contact for information, permits, and hands-on assistance. Mailing addresses and telephone numbers of coordinating offices for federal and state agencies are listed in the National Wildlife Federation Conservation Directory, which is published annually. Some key national groups and telephone numbers are listed below in the section on "Groups That Help Prevent and Control Wildlife Damage." Private pest control operators and local offices of government agencies that help control wildlife damage may be found in public telephone directories.

Keep in mind that permits may be required **before** control activities are initiated. When there is a possibility that endangered species or migratory birds will be affected, contact the US Fish and Wildlife Service. When game animals are involved, contact your state wildlife management agency. When aquatic habitats such as wetlands or streams may be affected, contact the US Army Corps of Engineers and your state environmental regulatory agency.

Special materials may be required to prevent and control wildlife damage. Chapters on individual species list information about such materials. Most items will be available from hardware and gardening supply stores. When pesticides are used, read labels carefully. You may need to contact USDA-APHIS-Animal Damage Control (ADC) or the Extension Service for explanation of some applications. The Pocatello Supply Depot operated by USDA-APHIS-ADC provides some chemical control agents for wildlife (see section below on the ADC Program). The **Pesticides** section in this handbook provides more details.

Effective techniques for controlling damage from wild animals do not exist for all situations. Information about research to solve special problems or international issues related to wildlife damage control may be obtained from the Denver Wildlife Research Center or the Jack H. Berryman Institute of Wildlife Damage Management at Utah State University. A section on wildlife damage research is presented below.

Attracting wildlife through feeding and habitat enhancement has gained popularity in recent years. This has resulted in greater appreciation of wildlife among urban residents and provides educational opportunities. Conflicts may develop, however, when wild animals concentrate near feeders and protected sites.

The key to enhancing urban wildlife is careful planning to develop compatible situations where the needs of wild animals are met without creating intolerable situations for people. Keep in mind that wild animals enjoyed by some people may cause problems for neighbors. The fox that one family likes to see in the backyard may be a serious problem for neighbors raising chickens, and the deer that people enjoy viewing from a distance may be a safety hazard on roads or may cause serious damage to ornamental plants and gardens in the community.

Groups that Help Prevent and Control Wildlife Damage

Cooperative Extension Service

The Cooperative Extension Service is a good place to start when you have a problem with wild animals and do not know where to obtain help. The extension service provides a wide range of information on prevention and control of wildlife damage through local agents in most counties and specialists at many state universities. Extension wildlife activities are coordinated nationally through the Natural Resources and Rural Development Program (202-720-5468). Local extension service offices are listed in government sections of telephone directories.

Animal Damage Control Program

USDA-APHIS provides operational and technical assistance to reduce conflicts between people and wildlife through the nationwide ADC, program. Help is available to states, individuals, and public and private organizations when wild animals damage livestock, poultry, beneficial wildlife, or crops including forests and rangelands. Help is also available when wild animals threaten human health and safety.

The ADC program includes a deputy administrator (202-720-2054), headquarters support staff, the Denver Wildlife Research Center, and the Pocatello Supply Depot. Operational activities are managed within most states through the eastern and western regional offices, and individual state offices. The Denver Wildlife Research Center (DWRC) (303-236-7826) is a major research facility devoted to improving methods and materials for vertebrate damage control. The Pocatello Supply Depot at Pocatello, Idaho (208-236-6920), manufactures and sells some toxicants, fumigants, and other products for wildlife damage management.

Fish and Wildlife Service

The US Fish and Wildlife Service has primary responsibility for managing endangered species and migratory birds. Contact the agency about required permits before initiating control activities that involve these species (Office of Management Authority, 800-358-2104).

State Wildlife and Fish Management Agencies

State wildlife and fish management agencies are responsible for managing most resident species of wildlife and fish, as well as migratory species while they are within state borders. Often permits are required from the state agency before species listed as game animals, furbearers, or game fishes can be controlled. Permits may also be required if species are involved that are considered rare or endangered by the state. Check with your local state wildlife and fish management agency when you obtain a permit for control from the US Fish and Wildlife Service.

Table 1. Sources of information (I), permits (P), and hands-on assistance (A) for wildlife damage control. The National Wildlife Federation *Conservation Directory* lists addresses and telephone numbers for coordinating offices for federal and state agencies. Public telephone directories list local government offices and private pest control operators.

SPECIES	USDA-APHIS-Animal Damage Control	Extension Service	US Fish and Wildlife Service	State wildlife and fish management agencies	Local animal control agencies	Private pest control operators
Mammal Predators						
Badgers	I	I		P		A
Bears	IA	I		IP		
Bobcats and lynx	IA	I		IP		
Cougars	IA	I		IP		
Coyotes	IA	I		IP		
Feral house cats	I	I		I	A	A
Feral dogs	IA	I		I	A	A
Foxes	IA	I		IP	A	
Opossums	IA	I		I	A	A
Otters	I	I		IP		
Raccoons	IA	I		IP	A	A
Skunks	IA	I		IP	A	A
Weasels	IA	I		IP		
Wolves	IA	I	P	IP		
Small Mammals						
Bats	I	I	P	I	A	A
Beavers	IA	I		IP		A
House mice	I	I			IA	A
Moles	I	I				A
Muskrats	IA	I		IP		A
Pocket gophers	I	I				A
Prairie dogs	IA	I	I	I		A
Norway rats	I	I			IA	A
Roof rats	I	I			IA	A
Rabbits	IA	I	I	IP	IA	A
Tree squirrels	I	I		P	IA	A
Voles	I	I				A
Big Game Mammals						
Bison	I	I		P		
Deer	I	I		IPA		A
Elk		I		IPA		
Feral swine	I	IA		IP		
Moose		I		IPA		
Pronghorns		I		IPA		
Birds						
Blackbirds	IA	I	I	I	I	A
Crows	IA	I	I	I		A
Ducks and geese	IA	I	IP	IP		A
Eagles	IA	I	IP	IP		
Egrets, herons, and cormorants	IA	I	IP	IP		
Hawks, falcons, and owls	IA	I	IP	IP		
Magpies	IA	I	I			
Pigeons	IA	I			I	A
House sparrows	IA	I			I	A
Starlings	IA	I			I	A
Turkeys		I		IP		
Woodpeckers	IA	I	IP	IP	I	A
Reptiles						
Alligators	I	I		IP		A
Snakes	I	I		I	I	A

Local Animal Control Authorities

The local animal control authority, public health service, or animal welfare organization, may be able to provide assistance with damage caused by urban wildlife, in situations in which humans are threatened by wildlife, and with free-ranging dogs and cats. Refer to government sections of your local public telephone directory.

Professional Pest Control Operators

Private pest control operators located throughout the United States provide a wide range of wildlife damage control supplies and services. Consult your telephone directory for local pest control operators. The National Animal Damage Control Association and the Urban Wildlife Management Association may be able to provide contacts for special control situations.

Research to Understand and Minimize Wildlife Damage

Research on ways to minimize damage caused by wild animals dates back to the nineteenth century. In the United States, most research on damaging wildlife has been conducted and/or funded by government agencies. Major research efforts date back to the establishment of the Section of Economic Ornithology within the US Department of Agriculture in 1885 (US Fish and Wildlife Service 1981). The section grew, and in 1905 became the Bureau of Biological Survey. The survey and cooperating universities conducted studies of pocket gophers and ground squirrels. The survey also supported research on predatory animals, mainly aimed at eliminating them to satisfy demands of the growing western livestock industry.

Controversy about controlling coyotes and other wild animals increased from the late 1920s through the 1970s. Opposition to control changed from a fringe position opposed to wild animal suffering in the 1930s to a well-organized, national movement concerned with environmental issues and animal welfare. The emphasis of wildlife damage control research also shifted from lethal control to nonlethal control techniques that include more studies of predator behavior.

Numbers of wildlife professionals involved in wildlife damage control declined through the 1960s and 1970s as controversy increased. By 1978 only 41 of 450 US and Canadian university and college wildlife faculty members surveyed reported an emphasis in the ecology and control of damaging vertebrates (Blaskiewicz and Kenny 1978).

In recent years, most research relating to problem wildlife has been conducted by personnel of the Denver Wildlife Research Center (DWRC) or has been supported by grants from the center. In 1986, the DWRC was transferred from the Fish and Wildlife Service to the Animal and Plant Health Inspection Service (APHIS).

The DWRC has national and international programs devoted to providing scientific information on wildlife damage, existing control practices, and alternative methods for reducing damage. About half of the staff is based in Denver; the rest are located at field stations on university campuses and other sites in the United States and cooperating countries.

The DWRC has cooperative ties with several universities. Colorado State University in Fort Collins has been a close cooperator with DWRC for many years. DWRC staff serve as instructors in some courses and advise and support research studies by university students. The DWRC has been particularly involved in short courses on wildlife damage research and management for foreign students. APHIS plans to move the DWRC headquarters to the Colorado State University campus. A master plan has been completed and construction of an animal facility was initiated in 1993.

Cornell University, in Ithaca, New York, has cooperated for five years with DWRC in conducting research on deer damage and its management. The university, along with the New York Cooperative Fish and Wildlife Research Unit, has conducted research on a variety of wildlife damage problems ranging from biological studies of pine voles to human perceptions of wildlife damage and control.

The Monell Chemical Senses Center on the Philadelphia campus of the University of Pennsylvania is a nonprofit research institute devoted exclusively to studies of taste, smell, and the common chemical sense. This institute has been involved with wildlife damage research since its inception in 1968. The DWRC has maintained a field station at the center since 1978. The center has focused on the role of the chemical sense in wildlife damage management, including bait shyness, food-aversion learning, attractancy, and repellency.

The University of Florida at Gainesville has worked cooperatively with a Gainesville-based field station of the DWRC on research leading to cultivars of blueberries that might improve resistance to depredation by some species of birds

The DWRC staff also work in collaboration with the Gainesville-based field station and Louisiana State University's Rice Research Station to study and control blackbird damage to rice. Research efforts are also devoted to the control of beaver damage in waterways.

Mississippi State University, in Starkville, has had a strong interest in wildlife damage research for many years, partly through the US Fish and Wildlife Service Cooperative Research Unit on the campus. Since the establishment of a field station of the DWRC on campus in 1988, the research has focused particularly on bird depredations to aquaculture. The Maine Cooperative Fish and Wildlife Research Unit has also had interest in cormorant depredations in aquaculture. The DWRC has assisted in the development and production of radiotelemetry equipment to allow tracking of movements of cormorants for both the Maine and Mississippi studies.

Bowling Green State University, in Ohio, has a strong research and educational program in wildlife damage management. The DWRC has cooperated in this program by sponsoring

research activities, and by classroom lectures and discussion. Plans are being developed to form close working relationships between the University and the DWRC field station at nearby Sandusky, Ohio. In the past, the field station program focused on blackbird population dynamics and damage to corn. More recent research has emphasized gull problems at airports and at sanitary landfills. The present leadership of Bowling Green State University is strongly supportive of continued programs in wildlife damage management.

North Dakota State University in Fargo has worked cooperatively with DWRC on reducing blackbird damage to sunflowers. The University has a long-term plant-breeding program that has produced two high-yield cultivars of sunflower that exhibit resistance to blackbird damage. Research at the field station is presently focused on alteration of cattail marshes to make them unsuitable as roosts for blackbirds and more suitable for other migratory birds.

Some cooperative studies are being conducted on the efficacy of DRC-1339 for blackbird control with the Jack H. Berryman Institute of Wildlife Damage Management at Utah State University, in Logan (801-797-2436). This new institute offers a broad research and graduate educational program focusing on innovative approaches to controlling wildlife damage. The purpose of the institute is to help wildlife damage management specialists and researchers do their jobs better and to foster communication.

Utah State University is also the site of a field station of DWRC that focuses primarily on predator control methods and their alternatives. The station is uniquely equipped with large penned areas for the study of coyote behavior. This station, along with its university-based cooperators, has been the source of many studies contributing to our present understanding of coyote biology, behavior, physiology, and population dynamics.

Washington State University in Pullman has had an active interest in a broad range of wildlife damage issues for many years, including the development of bird-repellent methods, animal-restraining systems, humane trapping standards, and control of rodent damage to orchards. The recent addition of a DWRC field station at the university is strengthening the program, particularly in rodent problems and their control. The Pullman station is closely tied with a DWRC field station at Olympia, which has focused for many years on wildlife damage to forests by species such as deer, mountain beavers, voles, and pocket gophers. These research programs assess the efficacy of existing control and look at repellent devices, food aversion learning, and chemical repellent systems. The work is also closely coordinated with the field station at Monell Chemical Senses Center in Philadelphia.

The University of California, at both Berkeley and Davis, as well as the University System's Research and Extension Center at Hopland, has had a strong and broad research and educational program in wildlife damage under the leadership of Dr. Walter Howard, professor emeritus of the University of California at Davis. The Berkeley scientific staff has had particular interest in deer damage and population dynamics, whereas the Hopland Center has contributed much to understanding and managing predator problems. The recent addition of a DWRC field station at the Berkeley location is providing opportunities for studies of predator behavior and population dynamics as well as alternative control approaches. Some of these projects are coordinated with studies of coyotes at Yellowstone National Park and the University of Montana at Bozeman.

In addition to field stations and collaborating scientists, DWRC has contracts with universities and other organizations to conduct research. Arizona State University in Tempe has contracted to conduct studies on food aversion learning as it relates to predator management. Several universities have participated in studies of contraception as a wildlife damage management tool. These include studies at Rutgers University in New Brunswick, New Jersey, on hormonal approaches to contraception of deer and studies at Baylor Medical College in Waco, Texas, and Pennsylvania State University in State College, Pennsylvania, on immunologically based approaches to contraception of deer. The DWRC has also supported student research at the University of Missouri-Colombia on human perceptions of goose management.

Although the DWRC continues to cooperate with universities, it has not cooperated formally with all universities that have an interest in or active research or educational programs in wildlife damage management. For example, the University of Nebraska-Lincoln has strong research and educational programs in wildlife damage management, as does Kansas State University in Manhattan. Both of these universities would be suitable candidates for closer cooperative efforts in the future. In general, cooperative research ties with universities have provided opportunities to assess new approaches to wildlife management. The ties have also served as recruitment pools for scientists and support staff for professional groups involved in wildlife damage management. The numerous cooperative ties with DWRC attest to a broad and continuing interest in wildlife damage management by many universities.

The director of the DWRC (303-236-7820), can serve as a source for further contacts with any of the universities and research programs described above.

Summary

An overview of sources of information about wildlife damage management is presented in Table 1. The table is not comprehensive because laws and services vary from state to state. Good starting places for information are local Cooperative Extension offices, state wildlife management agencies, and animal control authorities. They may refer you to USDA-APHIS-ADC or private wildlife damage control services in your area.

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WILDLIFE DISEASES AND HUMANS

INTRODUCTION

Diseases of wildlife can cause significant illness and death to individual animals and can significantly affect wildlife populations. Wildlife species can also serve as natural hosts for certain diseases that affect humans (zoonoses). The disease agents or parasites that cause these zoonotic diseases can be contracted from wildlife directly by bites or contamination, or indirectly through the bite of arthropod vectors such as mosquitoes, ticks, fleas, and mites that have previously fed on an infected animal. These zoonotic diseases are primarily diseases acquired within a specific locality, and secondarily, diseases of occupation and avocation. Biologists, field assistants, hunters, and other individuals who work directly with wildlife have an increased risk of acquiring these diseases directly from animal hosts or their ectoparasites. Plague, tularemia, and leptospirosis have been acquired in the handling and skinning of rodents, rabbits, and carnivores. Humans have usually acquired diseases like Colorado tick fever, Rocky Mountain spotted fever, and Lyme disease because they have spent time in optimal habitats of disease vectors and hosts. Therefore, some general precautions should be taken to reduce risks of exposure and prevent infection.

GENERAL PRECAUTIONS

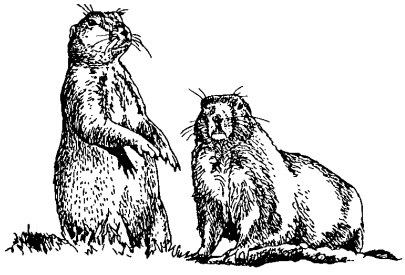
Use extreme caution when approaching or handling a wild animal that looks sick or abnormal to guard against those diseases contracted directly from wildlife. Procedures for basic personal hygiene and cleanliness of equipment are important for any activity but become a matter of major health concern when handling animals or their products that could be infected with disease agents. Some of the important precautions are:

1. Wear protective clothing, particularly disposable rubber or plastic gloves, when dissecting or skinning wild animals.
2. Scrub the work area, knives, other tools, and reusable gloves with soap or detergent followed by disinfection with diluted household bleach.
3. Avoid eating and drinking while handling or skinning animals and wash hands thoroughly when finished.
4. Safely dispose of carcasses and tissues as well as any contaminated disposable items like plastic gloves.
5. Cook meat from wild game thoroughly before eating.
6. Contact a physician if you become sick following exposure to a wild animal or its ectoparasites. Inform the physician of your possible exposure to a zoonotic disease.

Precautions against acquiring fungal diseases, especially histoplasmosis, should be taken when working in high-risk sites that contain contaminated soil or accumulations of animal feces; for example, under large bird roosts or in buildings or caves containing bat colonies. Wear protective masks to reduce or prevent the inhalation of fungal spores.

Protection from vector-borne diseases in high-risk areas involves personal measures such as using mosquito or tick repellents, wearing special clothing, or simply tucking pant cuffs into socks to increase the chance of finding crawling ticks before they attach. Additional preventive methods include checking your clothing and body and your pets for ticks and removing the ticks promptly after returning from infested sites. If possible, avoid tick-infested areas or locations with intense mosquito activity during the transmission season. Reduce outdoor exposure to mosquitoes especially in early evening hours to diminish the risk of infection with mosquito-borne diseases.

Equally important preventive measures are knowledge of the diseases present in the general area and the specific habitats and times of year that present the greatest risk of exposure. Knowledge of and recognition of the early symptoms of the diseases and the conditions of exposure are essential in preventing severe illness. Also



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

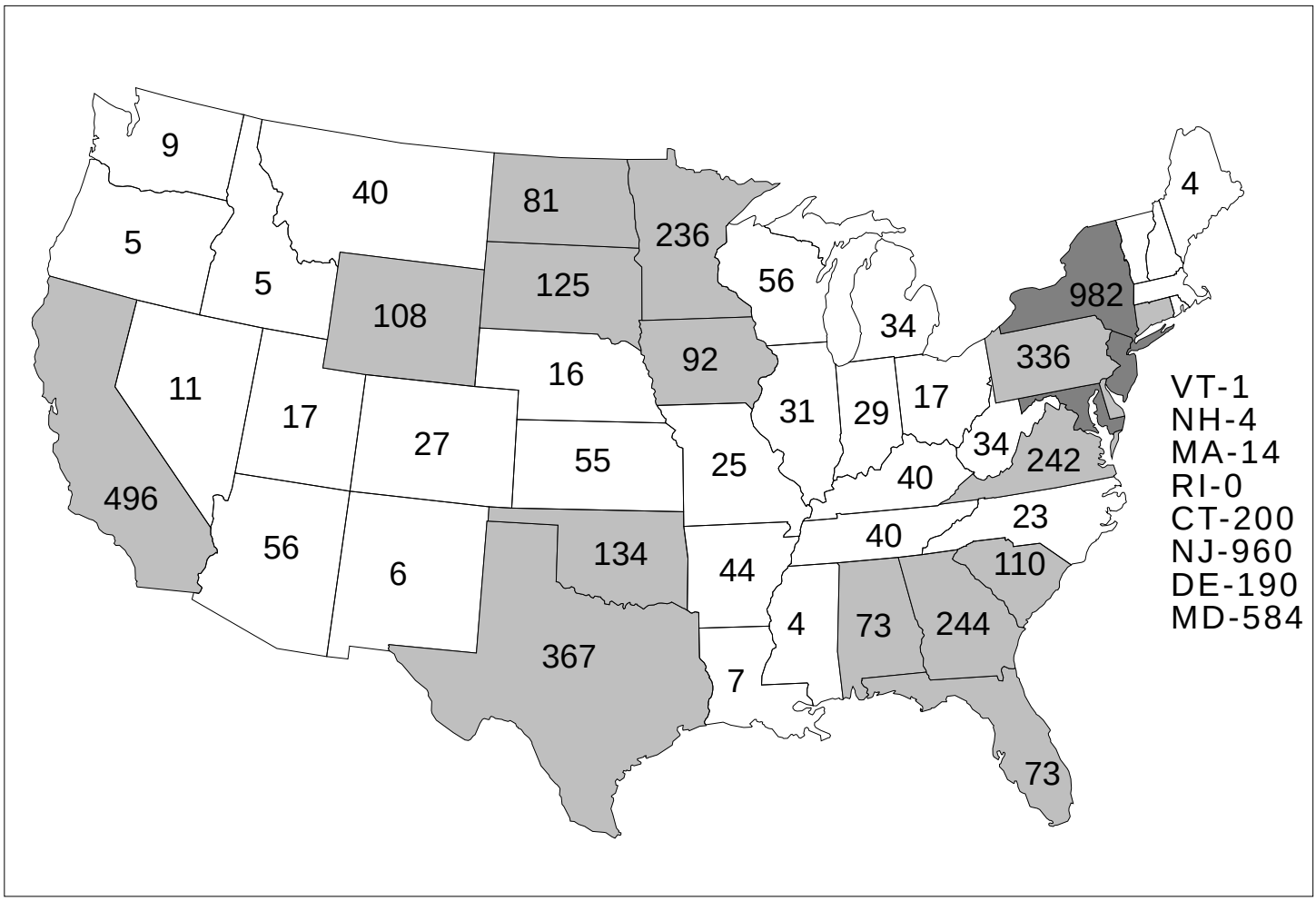


Fig. 1. Reported human cases of wildlife rabies in the United States, 1991.

important are medical evaluation and treatment with proper antibiotics. For example, if you become ill following some field activity in a known plague-endemic area and you recognize the early symptoms of the disease, seeking medical care and informing the attending physician of your possible exposure to plague will aid in the correct treatment of your illness and reduce the risk of complications or even death.

In addition to taking personal precautions, risk of acquiring vector-borne diseases can be reduced in specific locations through area-wide applications of insecticides to control mosquito or flea vectors or acaricides to control tick vectors. Reduction in host populations (for example, rodents) and their ectoparasites (fleas or ticks) may be needed to control transmission of such diseases as plague or Lyme disease. Vaccination of wildlife hosts as a means of reducing zoonotic diseases is currently being investigated and may soon be available for diseases like rabies.

WILDLIFE DISEASES OF PUBLIC HEALTH CONCERN

Directly Transmitted Diseases

Rabies

Rabies is an acute disease, caused by a virus (rhabdovirus), that can infect all warm-blooded animals, and is usually fatal. Certain carnivorous mammals and bats are the usual animal hosts (Fig. 1; Table 1). Rabies occurs throughout most of the world; only Australia and Antarctica are free of it. Most human cases have been contracted from rabies-infected dogs. In the United States, human cases have decreased to an average of one person per year (75% of cases are acquired outside the United States). Reduction in human rabies is likely linked with the intensive control of dog rabies during the 1950s and 1960s through massive vaccination campaigns, stray dog control programs, and improvement in human treatment following exposure. Nevertheless, thousands of people in the United States continue to receive treatment every year for possible exposure to rabies virus by animal bites. Most of the treatments are still due to dog and cat bites; however, these pet species have the lowest occurrence of reported rabies among all animal species tested.

Rabies in wildlife increased dramatically during the 1960s and now accounts for most of the reported animal rabies cases (91% in 1991). Some of the increase in reporting was due to real increases in the number of cases, and some was due to an increased awareness of wildlife rabies, particularly in striped skunks, raccoons, and bats. In 1991, 6,975 cases of animal rabies were reported in 49 states, the District of Columbia, and Puerto Rico. Raccoons (44.2%), striped skunks (29.7%), and various species of bats (9.9%) continued to be the major hosts. Red and gray foxes (4.6%), other wildlife species (2.8%), and domestic animals (8.9%) comprise the remainder of hosts. During the last 2 years, raccoons replaced striped skunks as the major wildlife host in the United States because of the continued expansion of raccoon rabies in the northeastern United States. Animal cases are reported throughout the year, although the number of cases reported reaches a seasonal peak for skunks in March and April, for raccoons in April, and for bats in August.

Clinical Signs. Rabies is considered almost 100% fatal once clinical signs develop. The disease progresses rapidly following the appearance of clinical signs, and the animal dies within a few days. Although abnormal behavior is not diagnostic for rabies (other diseases, like distemper, cause similar behavioral changes), atypical behavior and signs develop following brain infection, and rabies should be suspected whenever wild animals display unusual behavior.

Infected animals usually display either "furious" or "dumb" rabies, although some animals progress through both stages. Skunks, raccoons, foxes, and other canids usually have furious rabies and are unduly aggressive before convulsions and paralysis set in. Some animals, however, have dumb rabies and proceed to tremors and convulsions without agitation or aggression. Other behavioral changes include friendliness or loss of fear, appearance in the daytime for some typically nocturnal species (skunks, bats), unprovoked attacks on anything that moves (including inanimate objects), bewilderment, and aimless wandering. Unusual barking, crying, and frothing at the mouth are additional signs, which are the result of paralysis of the throat muscles. Occasionally, rabid bats are encountered prostrate or fluttering on the ground, unable to fly; they should be handled with care because they can still bite and transmit rabies. Some rabid bats, particularly solitary species like the hoary bat, are aggressive and have been known to attack people. In domestic animals, rabies should be suspected if there is any change in normal habits, such as sudden change in disposition, failure to eat or drink, running into objects, or paralysis.

Transmission. Rabies virus is transmitted primarily via the saliva during the bite of a rabid animal. However, other methods of transmission are possible. Accidental exposure of wounds or cuts to the saliva or tissues of infected animals can occur. The virus is also present in various body organs of infected animals, especially the brain and salivary glands, which poses a health hazard to persons who are field dressing or performing necropsies on these animals. In addition, aerosol exposure has occurred, although rarely, in caves containing very large populations of infected bats. Transmission between animals also occurs by ingestion of infected tissues and by transplacental passage to offspring.

When the virus enters the tissue of a susceptible animal or human, it multiplies at the bite or inoculation site and travels slowly up nerve fibers to the part of the brain that controls the bitten area. The virus multiplies there and spreads to other parts of the brain and eventually produces a variety of signs in the infected animal or person. The virus also spreads from the brain to other tissues, particularly to the salivary glands, where it multiplies and is released into the saliva. The virus is perpetuated in nature when an infected animal with virus in its saliva bites another animal.

The virus is rarely present in the salivary glands without first occurring in the brain and is present in the saliva for only a few days before clinical signs appear. Exceptions occur in a few species of bats and in a unique African virus strain found in dogs. The length of the incubation period (from the time the animal is bitten until clinical rabies appears) is usually 2 to 3 weeks, but varies from 10 days to several months.

Handling of Suspect Animals and Diagnosis. Use caution when approaching a suspected rabid animal since many are still aggressive and can bite even if paralyzed. If the animal is still alive, it should be killed humanely without damaging the head. To confirm whether an animal is infected with rabies, the animal must be submitted to the local health department or state diagnostic laboratory for testing.

Avoid exposure to any sick or dead animals that are suspected to have rabies. Handle any dead animal with gloves or with a plastic bag that can be turned inside-out to cover and contain the animal. Avoid direct skin contact with the animal. For large animals such as skunks and raccoons, remove the head cautiously and seal it in a plastic bag, avoiding contact or aerosol exposure. Seal the whole animal or head inside an additional plastic bag (double) and keep it cool at all times. Do not freeze the specimen unless a delay of several days is anticipated before it is examined for rabies. Disinfect gloves or knives that were in contact with the animal with a strong detergent or bleach or dispose of them.

For transport to the laboratory, place the double-wrapped specimen in a leak-proof container with a coolant (not wet ice). Send the container by bus or other prearranged transportation. Include information about the specimen (species, date, geographic data, behavior) and the names, addresses, and telephone numbers of the person submitting the specimen and of anyone exposed to the animal.

To test for rabies, a fluorescent antibody (FA) test is performed directly on brain tissue to distinguish rabies virus from other disease agents (like distemper virus) that could be present in the animal's brain. In some states, brain

material is inoculated into mice to demonstrate virus for those specimens that resulted in human exposure.

If a person or pet is exposed to an animal suspected of having rabies but that has not been captured, record a description of the suspect animal (species, behavior) and provide the description to public health officials or the attending physician to determine possible treatment.

Prevention and Treatment. The best treatment for rabies is prevention. Individuals at high risk of exposure to rabies, such as wildlife biologists, game wardens, animal control officers, animal handlers, and veterinarians should be vaccinated before potential exposure. Safe and highly effective vaccines are available through a physician or the local health department.

First aid should immediately be provided to a person who has been bitten by or had contact with a potentially rabid animal. Scrub the exposed site, including bite wounds, with soap and water or water alone and flush thoroughly. Then apply a strong first aid solution (iodine) or cream. First aid treatment is the most effective method of preventing infection by the rabies virus but should not preclude medical attention from a physician, hospital emergency room, or the local health department. Contact your physician or health department as soon as possible to determine dosage of rabies vaccine and whether antirabies serum is required. Inform the health care professionals about the rabid animal and the circumstances of the exposure (species of animal involved and its behavior, if the attack or bite from the animal was provoked, and what type of first aid was administered).

Hantavirus

Hantavirus includes a group of viruses that can cause a febrile illness in humans which can be accompanied by kidney, blood, or respiratory ailments and can sometimes be fatal. The febrile illness includes fever, headache, muscle aches, nausea, vomiting, and lower back pain. Field and commensal rodents are the natural reservoirs for viruses in this group and these viruses are found worldwide. Infected rodents shed virus in their urine, feces, and/or saliva and can remain chronically infected. The contaminated excreta from infected rodents are thought to be the source of virus for aerosol and direct (animal bite) transmission to other rodents and humans.

The recent discovery of a possible new hantavirus in the southwestern United States and its apparent increased virulence, has heightened the awareness of and concern for rodent-associated diseases. It produces produces respiratory distress and potential death in humans. Human cases and deaths from this viral infection were first reported in 1993 in the Four Corners area of Arizona, Colorado, New Mexico, and Utah and, more recently, throughout the United States. Preliminary information has incriminated the deer mouse (*Peromyscus maniculatus*) as the natural reservoir and source of human infection in that region. Individuals trapping and handling small rodents in this region should take increased precautions to reduce their exposure to this virus. They should at least wear surgical gloves and masks when processing rodents (contact CDC Hotline for more detailed and thorough safety information). Rodent control with careful handling and disposal of carcasses should be instituted at campsites or in cabins before they are occupied. The premises should be sprayed with detergents or diluted bleach before thorough cleaning. Wet-mopping is recommended. Dry sweeping and vacuuming may increase risk of producing airborne particles. Rodent harborage should be removed from premises and from the surrounding area. Exclude rodents where possible.

Trichinosis

Trichinosis may result in diahrrea, sudden edema of the upper eyelids, photophobia, muscle soreness and pain, skin lesions, thirst, sweating, chills, and weakness. Other respiratory and neurological symptoms may appear if treatment is delayed.

Trichinosis is contracted by eating infected meat which contains the encysted parasites. The parasites may remain infectious in meat which is raw or poorly cooked.

Trichinosis is caused by a nematode parasite which produces the disease in humans and domestic and wild animals. Evidence indicates that nearly all mammals are susceptible to infections with this parasite, which encysts in the muscle of the host and is then transmitted through consumption of infected flesh. As would be expected, the disease is most common in wild carnivores and scavengers.

As with other wildlife diseases, trichinosis is difficult to control in nature. However, certain steps can be taken to decrease the problem. Carcasses of carnivores and other meat-eating species should not be discarded in the fields or woods, but should be made unavailable by burying or other means. These carcasses also should not be fed to swine, dogs, or other domestic animals. Open garbage dumps should be replaced by the landfill type or other methods of disposal where wildlife will not have access to meat scraps. If open garbage dumps cannot be eliminated, rodent control programs should be initiated and the areas fenced to prevent scavenging by larger animals such as foxes. These steps would markedly reduce the problem of trichinosis in wildlife in the United States.

If carnivorous or omnivorous wildlife such as bears, bobcats, opossums, raccoons, or feral pigs are consumed by humans, the meat should be properly prepared by cooking, freezing, or curing to destroy any viable trichinae. Cooking to an internal temperature of 137^{o}F is deemed sufficient for pork, while freezing at 5^{o}F for 20 days, -10^{o}F for 10 days, or -20^{o}F for 6 days will kill trichinae. Curing should follow approved government regulations.

Mosquito-borne Encephalitis

Encephalitis is a disease caused by mosquito-borne viruses (arboviruses) that affect the central nervous system. Infections range from unapparent to mild, nonspecific illnesses (fever, headache, musculoskeletal pain, and malaise) to occasionally severe illness of the central nervous system resulting in permanent neurologic damage and possibly death. The four major types of encephalitis in the United States include St. Louis encephalitis (SLE), California encephalitis (CE primarily includes the LaCrosse virus [LAC]), eastern equine encephalitis (EEE), and western equine encephalitis (WEE). The distribution of these arboviruses varies (Fig. 2). SLE occurs throughout the United States (an epidemic occurred in central Florida in 1990 and Arkansas in 1991), WEE occurs west of the Mississippi River, EEE occurs east of the Mississippi River but mostly along the Atlantic and Gulf coasts and north-central states, and CE occurs in California and the eastern United States (LAC type). Human cases of arbovirus infection have a seasonal occurrence from mid- to late summer.

These distinct viruses naturally infect a variety of birds and mammals and are transmitted between animals by mosquito vectors. Occasionally, infected mosquitoes will feed on human or equine hosts that are "dead ends" for the viruses, with little or no chance of subsequent transmission to other mosquitoes. These viral infections may, however, result in severe illness or death in humans or horses (EEE and WEE). Only EEE and occasionally WEE viruses adversely affect wild vertebrates; for example, EEE causes death in ring-necked pheasants and other exotic game birds, house sparrows, red-winged blackbirds, whooping cranes, and other species. The wildlife hosts for LAC virus are the eastern chipmunk, tree squirrels, and foxes. The natural hosts for the other three viruses are mostly songbirds, although squirrels and jackrabbits may be involved in WEE transmission.

No treatment or commercial vaccine is available for humans, but vaccines for WEE and EEE are readily available for horses. The best preventive measures are personal protection against mosquito bites, especially avoiding exposure to mosquitoes during early evening hours, and the use of repellents. Mosquito populations can be reduced in an area by eliminating breeding sites for vector species. Killing adult mosquitoes with areawide applications of insecticides has been most effective in preventing epidemics.

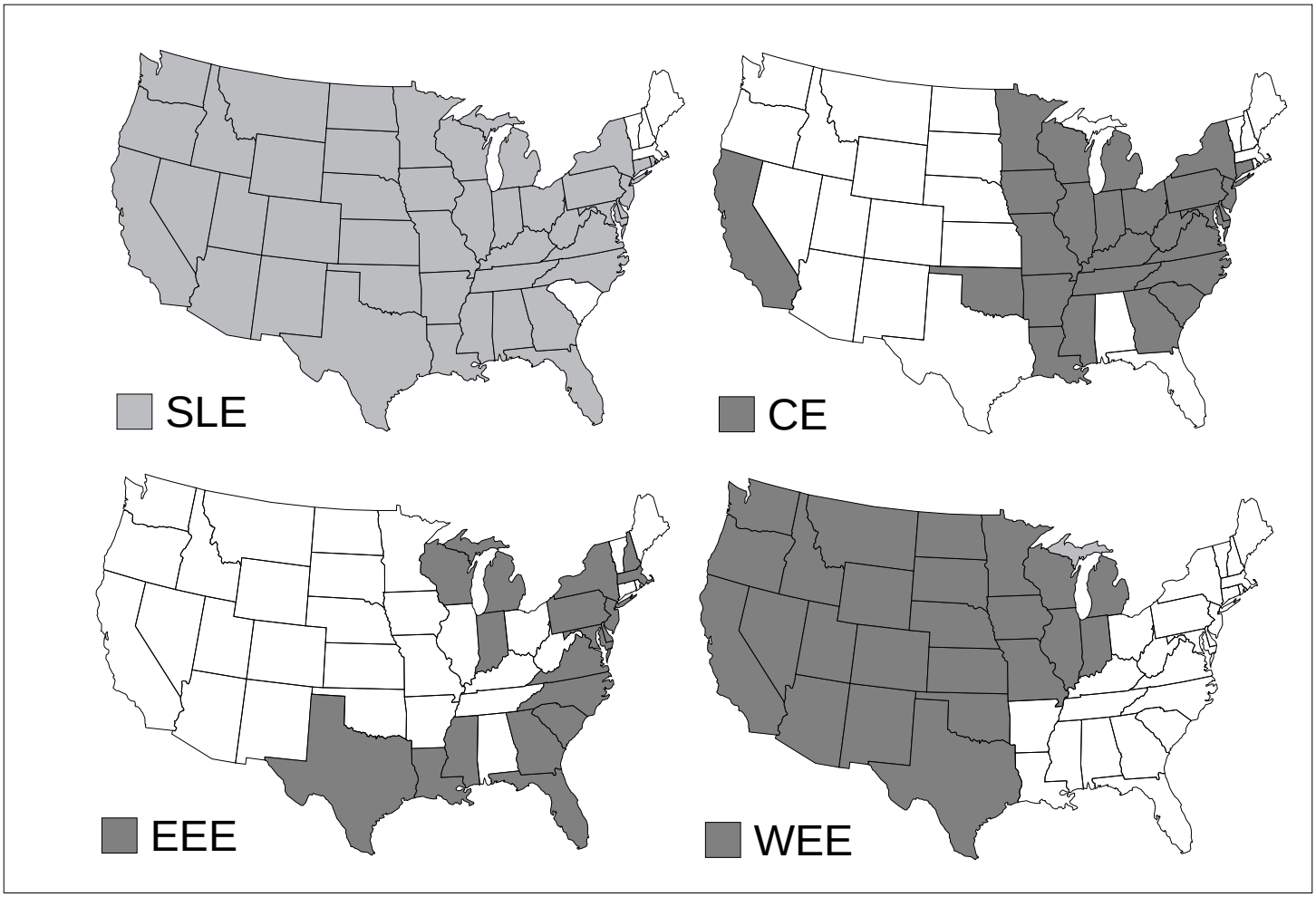


Fig. 2. Distribution of mosquito-borne encephalitis in the United States, 1964 to 1992; (a) St. Louis encephalitis (SLE); (b) California encephalitis (CE); (c) eastern equine encephalitis (EEE); and (d) western equine encephalitis (WEE).

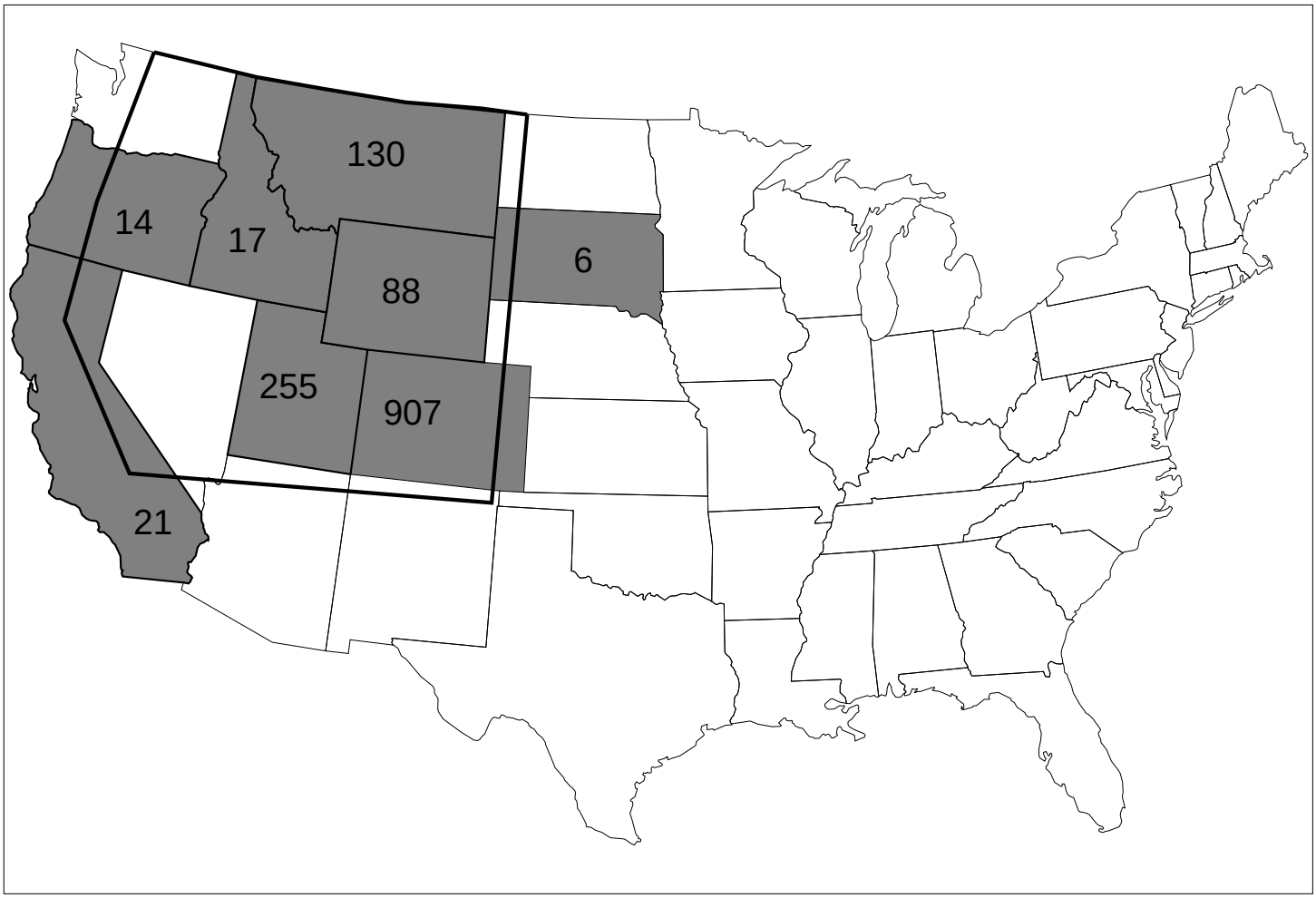


Fig. 3. Distribution of Colorado tick fever (human cases) in the United States, 1980 to 1988. (Solid line outlines distribution of *Dermacentor andersoni*.)

Tick-borne Diseases

Colorado Tick Fever

Colorado tick fever (CTF) is an acute and rather benign disease caused by a virus (coltivirus) that is transmitted to humans by ticks. Symptoms are usually limited to high fever, headache, muscle aches, and lethargy, but the symptoms are frequently biphasic and recurring. The disease is confined to the mountains or highland regions of eight western states and western Canada (Fig. 3). About 150 to 200 cases are reported each year; 1,438 cases were reported from 1980 to 1988 in eight western states, 63% of them in Colorado. CTF is transmitted to humans during the spring and early summer by the bite of the adult stage of the Rocky Mountain wood tick (*Dermacentor andersoni*) or by *D. occidentalis* in California. The virus is maintained in nature through transmission by immature stages of ticks to various species of small mammals, particularly chipmunks, ground squirrels, and deer mice during the spring and summer months. The virus survives the winter in infected tick nymphs and adults. The habitats that support the rodent hosts and tick vectors of the virus in the disease endemic region contain rocky surfaces with moderate shrub cover and scattered pines.

Avoid tick-infested habitats during spring and early summer and use personal protection against ticks. No vaccines or treatment are available.

Rocky Mountain Spotted Fever (Tick-borne Typhus)

Rocky Mountain spotted fever (RMSF) is a moderate to severe illness caused by a rickettsia (*Rickettsia rickettsii*). The disease is distinguished by a sudden onset of high fever, severe headache, muscle pain, and a red rash starting on the extremities about 3 to 6 days after onset of symptoms and extending to the palms of hands and soles of feet and then to the rest of the body. Delirium, coma, and death occur in about 1% to 2% of cases (15% to 20% in untreated cases). The disease is transmitted to humans in the United States by several hard tick (Ixodidae) species; *D. andersoni* in the Rocky Mountain region, *D. variabilis* in the east and southeast, and *Amblyomma americanum*

in the south-central states. In 1990, 649 cases of RMSF were reported from all regions of the United States, although more cases were reported in the south-Atlantic and south-central states (Fig. 4). The natural hosts for the rickettsia are a variety of wild rodents, although rabbits and wild and domestic carnivores are involved in some cases. The rickettsia survive the winter months in the tick vector and may be maintained by transovarial transmission from the female adult tick to its offspring.

Avoid tick-infested areas and use personal measures to protect against tick bites. No vaccine is presently licensed for public use, but antibiotic treatment is effective and should be initiated without waiting for laboratory confirmation of clinical diagnosis.

Lyme Disease

Lyme disease is caused by a spirochete bacterium (*Borrelia burgdorferi*) that is transmitted to humans by hard ticks. Early symptoms include a flu-like illness with headache, slight fever, muscle or joint pain, neck stiffness, swollen glands, jaw discomfort, and inflammation of the eye membranes. A diagnostic rash, erythema migrans (EM), occurs in 65% to 75% of the cases. The rapidly expanding red rash starts at the tick bite site and expands to a nearly circular lesion of about 1 to 8 inches (2 to 20 cm). It often has a bulls-eye appearance with central clearing and/or darkening around the edge. Additional smaller skin lesions may appear at other sites of the body and may last for days or weeks. Later symptoms, including heart, nervous system, and joint manifestations, may develop in untreated individuals. The joint pain and swelling usually occur one or more months after infection, may involve one or more joints, and may recur in different joints; the knee joint is most frequently affected. Domestic animals may be affected as well.

In 1992, 9,695 cases of Lyme disease were reported in 44 states (Fig. 5). Most cases were reported in the northeastern and upper midwestern states where the vector is the deer tick (*Ixodes scapularis*) and where transmission is predominately in residential communities. Other vectors are *I. pacificus* on the West Coast and possibly *A. americanum* in the Southeast and in

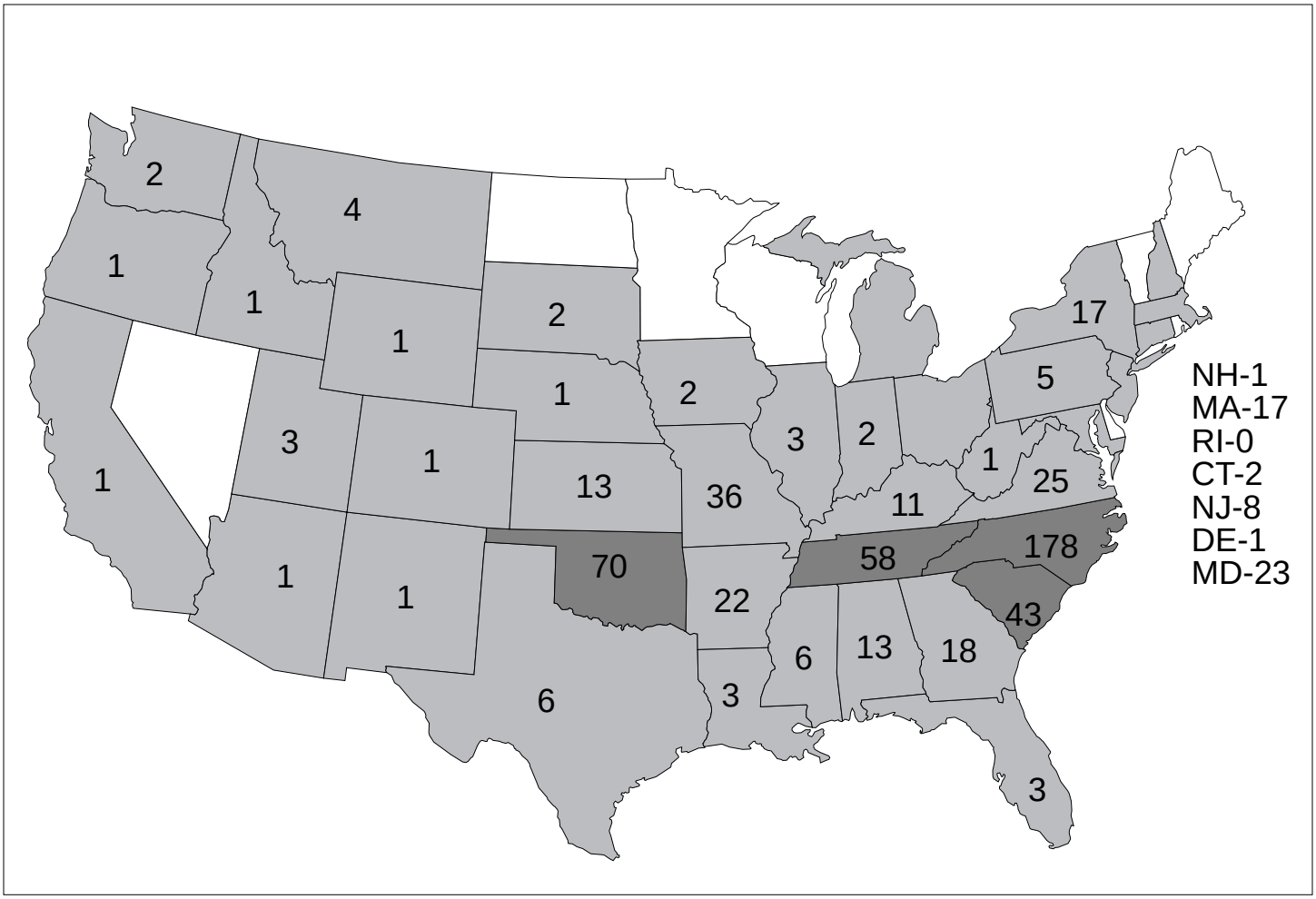


Fig. 4. Distribution of Rocky Mountain spotted fever (human cases) in the United States, 1990.

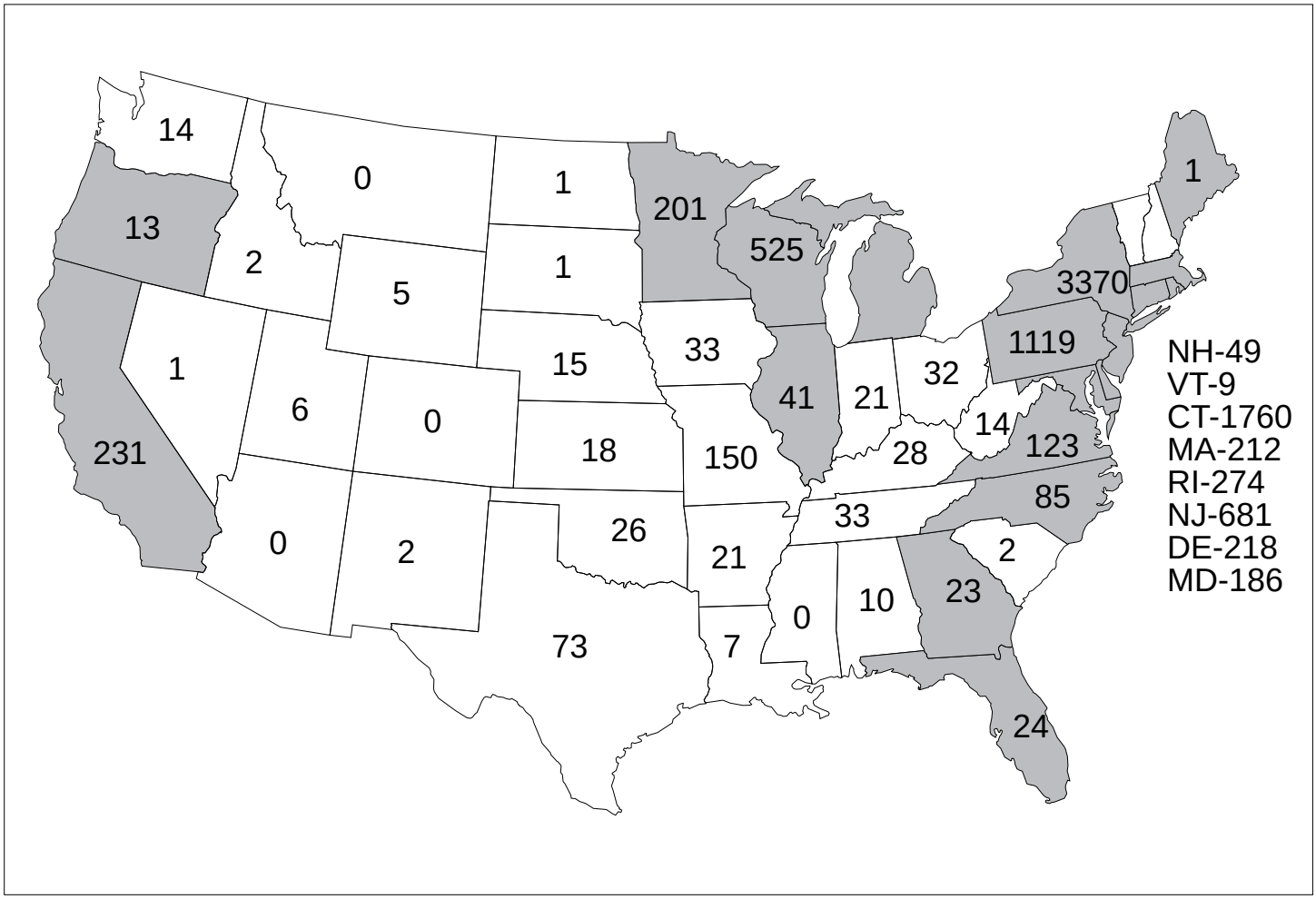


Fig. 5. Distribution of Lyme disease (human cases) in the United States, 1992.

south-central states. Transmission in these other regions of the United States may be more sporadic and occur during outdoor activities related to recreation and occupation. Acquisition of Lyme disease by humans peaks during the summer months when the tick nymphs are feeding on hosts. Because of its small size, the attached nymph frequently goes unnoticed and is not removed. The transmission cycle of Lyme disease begins when larvae acquire spirochetes while feeding on infected white-footed mice, chipmunks, other rodents, and birds. Engorged larvae drop to the ground, molt to the nymphal stage, and wait until the following summer to attach to and transmit spirochetes to susceptible rodents, birds, larger mammals, and humans. Uninfected larvae subsequently feed on these wild vertebrate hosts to complete the transmission cycle. The engorged nymphs drop to the ground and molt into adult ticks which are active during the fall and following spring and feed on large mammals, primarily deer. Deciduous forest is the predominant habitat for the tick vector and vertebrate hosts in the Northeast and Midwest. Other prime habitats include forested areas interspersed with residential development and grass and shrub areas, particularly along forest edges.

Patients treated with appropriate antibiotics during the early stages of the disease usually have rapid and complete recovery. Even patients treated during later stages generally respond well and recover. No vaccine is available except for domestic dogs. Avoid locations with ticks during seasonal activity periods, use personal measures to protect against ticks, become knowledgeable about the symptoms of Lyme disease, and seek medical care and treatment if infected.

Tularemia

Tularemia is caused by the bacteria *Francisella tularensis* and is characterized by sudden onset of high fever and chills, joint and muscle pain, and prostration. Slow-healing sores or lesions develop at the site of entry of the bacteria (or arthropod bite). Inflammation and swelling of nearby lymph nodes follow.

Tularemia is endemic throughout North America (Fig. 6). Most of the 100 to 300 cases reported each year are from the area between the Rocky Mountains and the Mississippi River (especially Arkansas and Missouri). Most cases are acquired during the summer months from vector transmis-

sion; however, a second peak of cases occurs during the winter and is probably associated with rabbit hunting and carnivore trapping.

The bacteria is maintained in rabbits, hares, rodents, and birds by tick transmission. The natural reservoir for the bacteria includes infected ticks and animal species that are less susceptible and thus survive acute infections. Hard ticks, primarily *D. andersoni*, *D. variabilis*, and *Haemaphysalis leporis-palustris*, and some flies, especially the deerfly (*Chrysops discalis*), can subsequently transmit the disease to humans. Tularemia can also be transmitted directly to humans. Transmission routes include drinking contaminated water; eating contaminated food or improperly cooked game meat; inhaling aerosols contaminated with rodent urine, feces, or dust; cuts from contaminated knives or other instruments; and scratches or bites from infected animals. Use personal protection measures against ticks and practice good sanitation procedures when handling wild animals, especially rabbits. Promptly seek medical care and treatment if symptoms develop.

Relapsing Fever

Relapsing fever can be caused by several *Borrelia* spirochete bacteria, which are related to the Lyme disease spirochete and are transmitted by soft ticks (Argasidae). Symptoms resemble Lyme disease except for the absence of the diagnostic rash and the presence of recurring fever. The most common type is caused by *B. hermsii*. Most human cases of this type of relapsing fever have been associated with log cabins or houses containing rodent nests (particularly of chipmunks and pine squirrels) and *Ornithodoros hermsi* ticks. This species of tick is active at night. Since it feeds rapidly and its bite is relatively painless, it may go unnoticed. The ticks feed on humans when the rodents disappear from the cabin nests because of rodent control measures or death from other diseases. Most human cases occur during the summer months when the cabins are in use. Sporadic cases are reported primarily in the mountainous regions of the western United States and British Columbia; 159 cases were reported during 1985 to 1991 in 10 western states (Fig. 7). Two outbreaks occurred among tourists and staff staying in cabins at the Grand Canyon in Arizona in 1973 and 1990. Inspect cabins for rodent use and nests, promptly remove nests, and treat cabins with insecticides or fumigate to kill any remaining ticks. Rodent-proof cabins to prevent rodent entry.

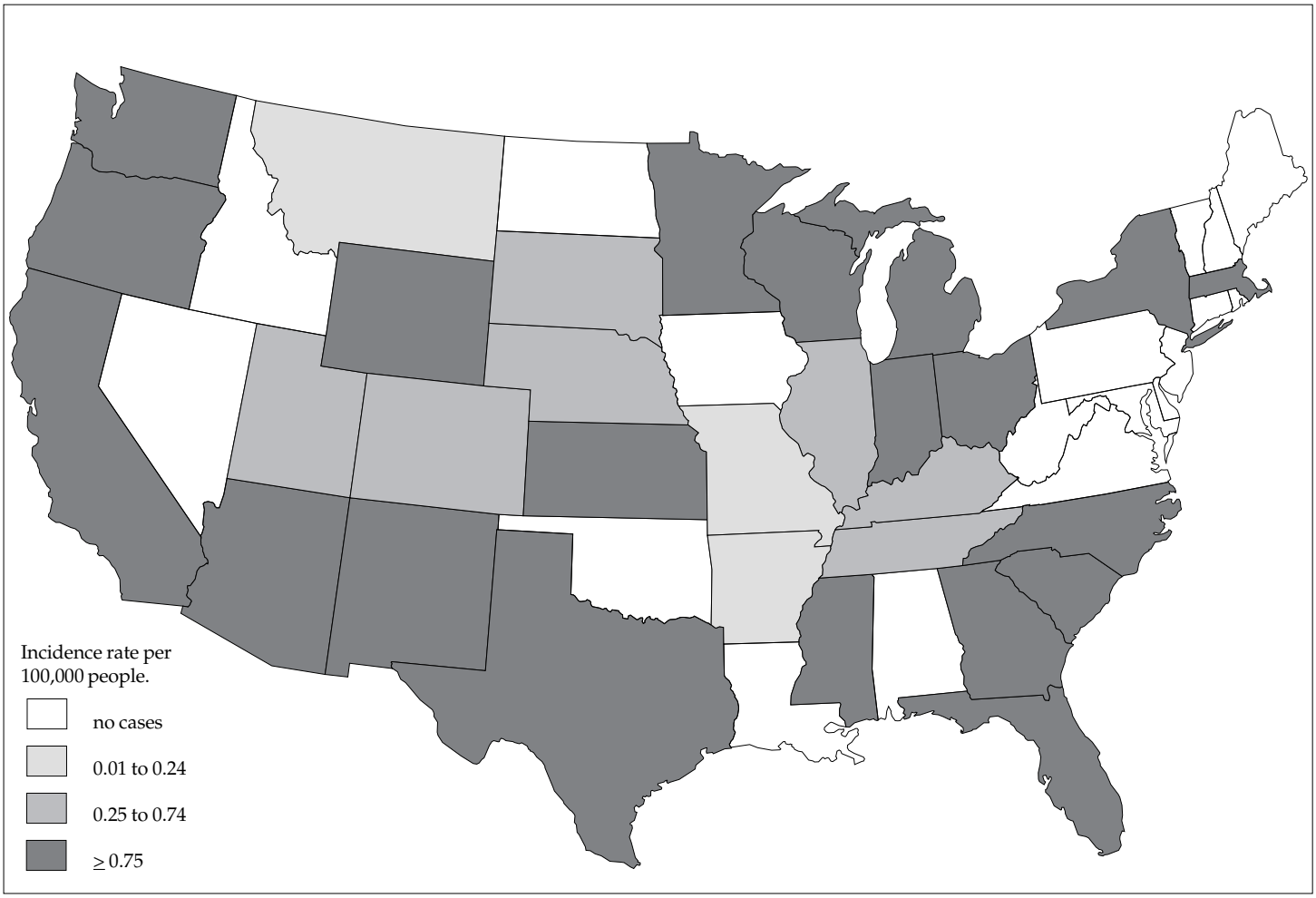


Fig. 6. Distribution of tularemia (human cases) in the United States, 1991 (191 cases reported).

Fig. 7. Distribution of relapsing fever (human cases) in the United States, 1985 to 1991.

Two other species of relapsing fever spirochetes are transmitted occasionally to humans in the western United States by *Ornithodoros* ticks. The spirochete *B. parkeri* is transmitted by *O. parkeri*, mostly in California, and *B. turicatae* by the tick *O. turicata*. Five humans were infected with *B. turicatae* in Texas in 1990 following exploration of a cave containing infected ticks. For prevention, use personal protection against tick exposure. If sick with relapsing fever, seek medical care and appropriate antibiotic treatment.

Other Tick-borne Diseases

Three other tick-borne diseases occur in the United States. Human ehrlichiosis is a recently recognized disease caused by a rickettsia, *Ehrlichia chaffeensis*. It is probably transmitted by ticks. Symptoms are similar to those of RMSF: an acute fever with headache, muscle ache, and nausea. A rash appears less frequently and for a much shorter duration. From 1986 to 1991, 262 cases and 4 fatalities were reported in 23 states, the majority occurring in Missouri and Oklahoma. Use personal protection against ticks and seek medical care and treatment if sick.

Powassan encephalitis is caused by a virus (flavivirus) which is transmitted by the ticks *I. cookei*, *D. andersoni*, and other *Ixodes* spp. Symptoms include the sudden onset of fever, sore throat, sleepiness, headache, and disorientation. Encephalitis, meningitis, and, occasionally, partial paralysis may develop. Natural hosts are marmots, sciurid rodents, rabbits, hares, carnivores, and possibly birds. Only 19 cases have been reported, all in New York, Pennsylvania, Ontario, and Quebec. Use personal protection to reduce exposure to ticks. No treatment is available.

Babesiosis is a protozoan disease with gradual onset of fever, sweating, loss of appetite, fatigue, general muscle ache, and possibly prolonged anemia. The disease can be severe and sometimes fatal. A protozoan, *Babesia microti*, is transmitted among wild rodents, particularly white-footed mice, by the tick *I. scapularis* along the coastal areas of New England and on adjacent offshore islands. This tick may be infected occasionally with both *B. microti* and the Lyme disease spirochete. Use personal protection measures to prevent tick exposure and seek medical care if sick.

Personal Protection

The following personal measures can protect against tick-transmitted diseases:

1. When possible, avoid tick-infested areas.

2. To better see crawling ticks, tuck pant legs into socks and tape the tops of socks over pant legs. Wear light-colored clothes.
3. Use tick repellent on exposed skin (DEET) or treat clothes with permethrin. Follow label instructions for use.
4. Check yourself frequently for ticks and remove them.
5. After outdoor activity, remove and wash field clothing promptly and dry clothes at a high temperature.
6. Inspect your body carefully and remove attached ticks with a pointed tweezers. Grasp ticks as close to the skin as possible and pull them loose with a slow, steady motion.
7. Inspect pets carefully for ticks and remove ticks soon after returning from the outdoors.

Flea-borne Diseases

Plague

Plague is an acute disease caused by the bacteria *Yersinia pestis*. Humans usually become infected by the bites of infected fleas but also directly from exposure to tissues or body fluids from diseased animals, especially when skinning animals. The disease is characterized by the sudden onset of fever and chills, followed by the development of swollen and painful lymph nodes (buboes) in the armpits, groin, and other areas 2 to 6 days following exposure. In addition to the bubonic form, septicemic infection may develop and involve other organs. Secondary infection of the lungs may lead to primary plague pneumonia, which then can be transmitted from person to person by aerosol. The disease may be only mild and short-lived but frequently progresses to a severe form, with 25% to 60% fatality in untreated cases. In the United States, plague is maintained in wild rodent populations in the western states by flea transmission between rodents. Sylvatic plague may persist in these animal populations with varying severity, depending on the species' resistance. Prairie dogs are susceptible to sudden die-offs. Outbreaks of plague have decimated prairie dog colonies in less than 1 to 2 years. Rabbits, hares, carnivores, and wild ungulates have also been infected occasionally. Human cases of plague are reported most frequently in New Mexico, Arizona, California, Colorado, and Oregon (Fig. 8). More than 50% of the 284 cases in the United States reported from 1970 to 1990 were in New Mexico. Use insect repellents on skin or treat field clothes with permethrin. Practice good sanitation procedures when handling animals. Seek medical care and treatment if sick.

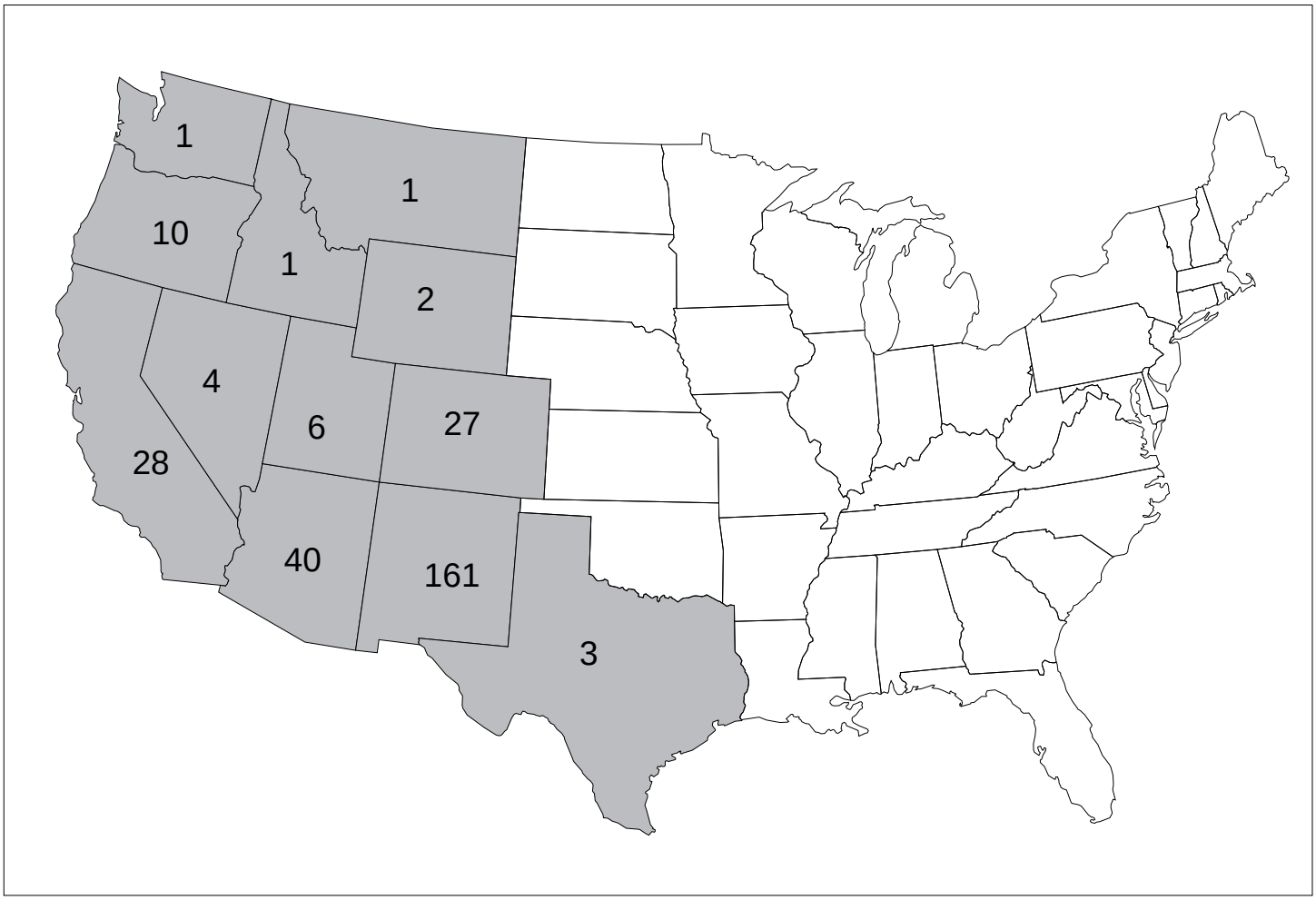


Fig. 8. Distribution of plague (human cases) in the United States, 1970 to 1990.

Murine Typhus Fever

Murine typhus fever is caused by *Rickettsia typhi*, a rickettsial organism that occurs throughout the southeastern and Gulf Coast states and southern California. Rats are the reservoir animals from which the disease reaches many humans by way of rat fleas. The oriental rat flea, *Xenopsylla cheopis*, is considered the most important vector of the disease. The causative organism enters the bloodstream when feces of infected fleas are scratched or rubbed into a flea-bite wound or other breaks in the skin. Murine typhus is similar to epidemic or louse-borne typhus, but illness is much milder and the fatality rate in untreated cases is much lower.

Commensal Rodent-borne Diseases

Rats and mice are responsible for the spread of over 35 diseases, either directly, through contamination of human food with their urine or feces, or indirectly, by way of rodent fleas and mites. Following are brief descriptions of the more common of these diseases.

Rat-bite Fever

Rat-bite fever is caused by the bacteria *Streptobacillus moniliformis*, which is found on the teeth and gums of rats. It is transferred from rats to humans by the bite of the rat. The most frequently occurring rat-bite fever in the United States is called Haverhill fever. It is similar to the rat-bite fever of the Orient called *sodoku* (caused by *Spirillus minus*).

Leptospirosis (Weil's Disease)

Leptospirosis is a mild to severe infection that is seldom fatal. Human cases of the disease result from direct or indirect contact with infected urine of rodents and other animals. The spirochetes (*Leptospira* spp., primarily *L. icterohemorrhagiae*) are found in contaminated water or on food, and may enter humans through mucous membranes or minute cuts or abrasions of the skin. Thus, Weil's disease is often found in sailors, miners, sewer workers, and fish or poultry dealers. In a recent study in Hawaii, Norway rats, roof rats, and house mice were found to have high *L. icterohemorrhagiae* carrier rates.

Symptoms of leptospirosis infection range from none to severe, with acute fatalities. Many infections are characterized by diarrhea, chills, vomiting, myalgia, and kidney damage. Prevention is the most important means of dealing with this disease. Proper sanitation, rodent-proofing, and food storage and handling are essential. Medical attention is typically required.

Salmonellosis

The *Salmonella* group of bacteria exists nearly everywhere in the environment and, unfortunately, several serotypes are pathogenic to humans and other animals. Salmonellosis can lead to severe cases of gastroenteritis (food poisoning), enteric fever septicemia (blood poisoning), and death. Food poisoning, the most common malady, is characterized by a sudden onset of abdominal pain, diahrrea, nausea, and vomiting. Due to the severity of this disease, medical attention is typically required.

Salmonella bacteria recognize few host barriers and are transmitted in many ways. One common form of transmission is through food contaminated by rat or mouse feces that contain *Salmonella* (especially *S. typhimurium*) organisms. It may also be spread by birds, which contaminate food with their feces or bacteria carried on their feet.

As with leptospirosis, the most important means of reducing the potential of this disease is through proper sanitation, rodent-proofing, and food storage and handling. Rodent control through trapping and appropriate use of toxicants may also be necessary.

Rickettsialpox

Rickettsialpox is a mild nonfatal disease resembling chicken pox. It is caused by a rickettsia (*Rickettsia akari*), which is transmitted from house mice to humans by the bite of an infected house mouse mite (*Liponyssoides sanguineus*). In this country rickettsialpox has been reported in Boston, West Hartford, New York, Cleveland, and Philadelphia.

Bird-borne Diseases

Large roosting concentrations of birds can be noisy, and the associated droppings can be a nuisance because of the objectionable odor and mess. In addition, birds may carry and transmit diseases to livestock and humans. Collections of droppings may provide a medium for bacterial and fungal growth that could pose a potential public health problem. Birds should be dispersed or controlled when they form large concentrations near human habitations and are judged to pose a threat to public health or livestock. Concentrations of birds that do not threaten human health or agriculture are usually better left undisturbed.

Histoplasmosis

Histoplasmosis is a respiratory disease in humans caused by inhaling spores from the fungus *Histoplasma capsulatum*. Birds do not spread the disease directly — spores are spread by the wind and the disease is contracted by inhalation. Bird droppings enrich the soil and promote growth of the fungus. Notable sources for histoplasmosis infection include: (1) traditional bird roosts, (2) poultry farms, (3) enclosed buildings where birds or bats have roosted, and (4) natural or organic fertilizers. In addition, the fungus can grow in various natural soils, with or without droppings. In some areas, such as the Ohio Valley, histoplasmosis is so widespread that 95% of the human population becomes infected, whether associated with birds or not.

Infection by only a few spores generally produces a mild case in humans and people are often unaware that they have contracted the disease (unless it is detected later through a skin reactivity test or lung X ray that reveals healed lesions). A more severe infection may result in an acute respiratory illness with flu-like symptoms

(in fact, histoplasmosis is often misdiagnosed as flu). The most serious infections, usually resulting from massive spore inhalation, may involve a dissemination of the fungus through the blood stream. Such cases may become chronic, recurring at later times, and affect organs other than the lungs. Treatment with an antifungal agent such as amphotericin B or imidazole ketoconazole may be prescribed in more severe cases.

Not all blackbird or starling roosts pose immediate public health problems related to histoplasmosis. The histoplasmosis fungus grows readily in the soil beneath bird roosts, but it cannot form spores under the acidic conditions of fresh droppings. An active, undisturbed roost may only give off a few spores. Old or abandoned roosts, however, can pose a significant threat to human health. After the droppings have dried out or been leached by the rain, the right conditions develop for spore release. If the soil is stirred up under dusty conditions, as may be the case in land clearing or bulldozing, massive amounts of spores may be released. Severe epidemics have occurred in association with bird roosts under such conditions.

Birds in large roosts can be dispersed by the use of various frightening devices or by roost thinning or clearing (see **Bird Dispersal Techniques**). Precautions should be taken when working around an old or abandoned roost site. It is wise to test for the presence of histoplasmosis before beginning any work. Wear a self-contained breathing apparatus or face mask with a dust filter (less than 2 microns) to prevent inhalation of the spores. Wear protective clothing, gloves, and boots that can be removed and disinfected with formalin and washed. If an area that was once a bird roost is going to be cleared or bulldozed, the area should be dampened with water or work should be done when the weather is wet or cold or both. Avoid working under dry, dusty conditions in late summer. A roost may be decontaminated by spraying it with a 3% to 5% solution of formaldehyde before clearing, but this option is very expensive.

Ornithosis (*Chlamydia psittaci, psittacosis*)

Ornithosis is an infectious respiratory disease caused by *Chlamydia psittaci,* a viruslike organism that affects humans, pets, and livestock. It usually leads to a mild pneumonia- or flu-like infection, but it can be a rapidly fatal disease (less than 1% of the cases reported in the United States). In humans many cases occur that are undetected or incorrectly diagnosed. Pigeons are most commonly associated with the transmission of ornithosis to humans. Birds have adapted to the disease and show no symptoms, but act as healthy carriers, shedding the organism in their feces, which later may become airborne as dust. The disease may also be contracted from parakeets, farm poultry, or waterfowl.

People working in dry, dusty areas where bird droppings are present, should wear face masks or respirators to avoid inhaling airborne avian fecal material. Spray work areas with water and/or disinfectants to minimize the potential for airborne infections particles. Medical attention, including antibiotic treatments are recommended for disease treatment.

Salmonellosis

The *Salmonella* group of bacteria can also be transmitted by birds. Refer to Commensal Rodent-borne Diseases (above) for additional information.

Other Bird-borne Diseases

Pigeons, starlings, sparrows, blackbirds, and other types of birds have been implicated in the transmission of various diseases of significance to humans or livestock. Starlings have been shown to be vectors of transmissible gastroenteritis (TGE) of swine. The virus can be carried in an infective state in the birds' intestines or on their feet for up to 30 hours. It is generally fatal to baby pigs and causes weight loss in adults. Starlings may also be involved in the transmission of hog cholera. Cryptococcosis is a fungal disease spread by pigeons and starlings that results in chronic, usually fatal, meningitis. Various species of birds may also play a part in the transmission of encephalitis, Newcastle disease, aspergillosis, toxoplasmosis, pseudotuberculosis, avian tuberculosis, and coccidiosis.

Conclusion

Wildlife workers tend to ignore the risks associated with handling wildlife species and working in natural environments. Diseases of wildlife or diseases present in their habitats can infect humans and some can cause serious illness or even death. Becoming aware of the potential diseases present and taking precautions to decrease exposure will greatly reduce chances of becoming infected with one of these diseases. This section provides a description of the major zoonotic diseases of wildlife in the United States that can also infect humans and gives information on disease prevention. Other diseases are briefly listed in Table 1 or can be found in one of the selected references.

You can prevent infection with zoonotic diseases and reduce the seriousness of an illness by observing the following recommendations:

1. Become aware of which zoonotic diseases are present in your area and their clinical symptoms.
2. Obtain any preexposure vaccinations that are available, particularly for rabies.
3. Take personal precautions to reduce exposure to disease agents and vectors such as ticks, mosquitoes, and fleas.
4. Practice good sanitation procedures when handling or processing animals or their products.
5. If you become ill, promptly seek proper medical treatment and inform the physician about possible exposures.

Acknowledgments

Portions of this chapter were derived from F. R. Henderson. 1983. Wildlife diseases and man. *in* R. M. Timm, *Prevention and Control of Wildlife Damage.* Univ. Nebraska Coop. Ext. Lincoln.

For Additional Information

For further information, consult the local or state health department or contact the CDC Voice Information System, Centers for Disease Control and Prevention, Atlanta, Georgia, at (404) 332-4555.

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Table 1. Some important wildlife diseases that affect humans.

Disease	*Parasite (Agent)*	*Method of Transmission*	*Wildlife Hosts*	*Type of Human Illness*
Direct				
Rabies	Virus (rhabdovirus)	Animal bite, aerosol	Striped skunk, raccoon, foxes, bats, and other mammals	Paralysis, convulsions, coma, death
Hantavirus	Virus (hantavirus)	Aerosol, animal bite	Deer mice, other wild and commensal rodents	Fever, headache, muscle aches, nausea, vomiting, back pain, respiratory syndrome
Leptospirosis	Bacteria (*Leptospira* spp.; *icterohemorrhagiae*)	Urine contamination, ingestion	Commensal and wild rodents, rabbits, fox, skunk, raccoon, opossum, deer	Fever; jaundice; neurologic; pain in abdomen, joints, or muscles; nausea; may be fatal
Brucellosis	Bacteria (*Brucella* spp.; *abortus*)	Contamination, ingestion (milk, etc.)	Hoofed animals (coyote)	Intermittent fever, chills, headache, body aches, weakness, weight loss
Rat-bite fever	Bacteria (*Streptobacillus moniliformis*)	Rodent bite	Commensal rodents	Abrupt onset with chills and fever, headache, muscle ache, followed by rash on legs and arms, arthritis
Salmonellosis	Bacteria (*Salmonella* spp.)	Ingestion of bacteria in food contaminated with feces	Rodents, swine, cattle, wild birds, poultry, pet turtles	Sudden onset of headache, fever, abdominal pain, nausea, diarrhea, vomiting
Ornithosis (Psittacosis)	Chlamydia (*Chlamydia psittaci*)	Inhalation of contaminated air	Parrot and sparrow-like birds, pigeons, waterfowl, domestic birds	Fever, chills, headache, muscle pain, loss of appetite, sweating, pneumonia
Histoplasmosis	Fungus (*Histoplasma capsulatum*)	Inhalation of spores	None, grows in soil enriched by feces under bird and bat roosts	Mild fever and influenza-like illness, pneumonia, hepatitis, endocarditis, death
Cryptococcosis	Fungus (*Cryptococcus neoformans*)	Inhalation is suspected	None, grows in droppings in pigeon nests	Meningitis; lung, liver, and bone infection; skin lesions or ulcers
Trichinosis	Nematode worm (*Trichinella spiralis*)	Ingestion of uncooked meat containing larval cysts	Swine, bear, wild and domestic carnivores, wild and domestic rodents	Nonspecific gastroenteritis, loss of appetite, nausea, diarrhea, swollen eyelids, fever, chills, muscle aches
Ascarid roundworm	Nematode (*Baylisascaris procyonis*)	Ingestion of nematode eggs (raccoon feces contamination)	Raccoon	Larval stage invades and damages body organs, including brain
Direct and Indirect				
Plague	Bacteria (*Yersinia pestis*)	Contamination from skinning animals, fleas	Wild rodents (prairie dogs, ground and tree squirrels, chipmunks), rabbits, carnivores	Fever, headache, severe discomfort, shaking chills, pain in groin or arm pits (swollen lymph nodes), death

Table 1. Some important wildlife diseases that affect humans (continued).

Disease	*Parasite (Agent)*	*Method of Transmission*	*Wildlife Hosts*	*Type of Human Illness*
Direct and Indirect				
Tularemia	Bacteria (*Francisella tularensis*)	Contamination from skinning animals, ticks, biting insects	Wild rodents, rabbits, hares, carnivores, birds, hoofed animals	Mild illness to severe meningitis, pneumonia, ulcer at inoculation site, swollen lymph nodes, death
Indirect				
Tick-borne				
Colorado tick fever	Virus (coltivirus)	Tick, *Dermacentor andersoni*, *D. occidentalis*	Wild rodents (sciurids, porcupine), hares, rabbits, marmots, carnivores	High fever, headache, muscle ache, lethargy, biphasic symptoms
Rocky Mountain spotted fever	Rickettsia (*Rickettsia rickettsii*)	Tick, *D. andersoni*, *D. variabilis*, *Amblyomma americanum*, *Haemaphysalis leporispalustris*	Wild rodents, rabbits, hares, carnivores, birds	Rapid onset, fever, headache, muscle aches, nausea, vomiting, abdominal pain, rash, loss of muscle control, possibly fatal
Ehrlichiosis	Rickettsia (*Ehrlichia chaffeensis*)	Tick, species unknown	Unknown, possibly dogs and other carnivores	Fever, headache, nausea, vomiting, muscle aches, fleeting rash
Lyme disease	Bacteria (*Borrelia burgdorferi*)	Tick, *Ixodes scapularis*, *I. pacificus*, *A. americanum*	Wild rodents (*Peromyscus*, chipmunks), raccoon, deer, rabbits, birds	Skin lesion (EM), fever, headache, fatigue, muscle ache, stiff neck, cardiac and neurologic manifestations, arthritis
Relapsing fever	Bacteria (*Borrelia hermsii*, *B. parkeri*, *B. turicatae*)	Tick, *Ornithodoros hermsi*, *O. parkeri*, *O. turicata*	Wild rodents (chipmunks, tree squirrels), particularly in cabins and caves	Rapid onset, severe headache, muscle weakness, rigor, joint pain, recurring fever
Babesiosis	Protozoa (*Babesia microti*)	Tick, *I. scapularis*	Wild rodents (white-footed mice, meadow vole)	Gradual onset, loss of appetite, fever, sweating, fatigue, general muscle aches, prolonged anemia, sometimes fatal
Tularemia (listed above)				
Mosquito-borne				
St. Louis encephalitis	Virus (flavivirus)	Mosquito, *Culex pipiens* complex, *Cx. tarsalis*, *Cx. nigripalpus*	Birds (mostly songbirds and waterbirds), some rodents	Fever, headache, musculoskeletal aches, malaise, low fatality
Eastern equine encephalitis	Virus (alphavirus)	Mosquito, *Culiseta melanura*, *Aedes* spp.	Birds (mostly songbirds and waterbirds), bats	Fever, intense headache, nausea, vomiting, muscle, aches, confusion, coma, high fatality

Table 1. Some important wildlife diseases that affect humans (continued).

Disease	*Parasite (Agent)*	*Method of Transmission*	*Wildlife Hosts*	*Type of Human Illness*
Indirect				
Western equine encephalitis	Virus (alphavirus)	Mosquito *Cx. tarsalis*	Birds (mostly songbirds and waterbirds), jackrabbits, rodents	Fever, headache, nausea, vomiting, malaise, loss of appetite, convulsions, low fatality
California encephalitis (LaCrosse)	Virus (bunyavirus)	Mosquito *Ae. triseriatus*	Eastern chipmunk, tree squirrel, red fox, deer mouse	Fever, irritability, headache, nausea, vomiting, loss of muscle control, confusion, coma, low fatality
Louse-borne				
Louse-borne typhus	Rickettsia (*Rickettsia prowazekii*)	Body louse *Pediculus humanus*, animal contact	Humans, flying squirrels	Onset variable, fever, headache, chills, general pains, prostration, skin rash after 5 to 6 days
Flea-borne				
Flea-borne typhus (Murine)	Rickettsia (*Rickettsia typhi*)	Rat flea *Xenopsylla cheopis*	Domestic rats, wild rodents, opossum	Fever, severe headache, chills, general pains, possibly skin rash
Plague (listed above)				