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IDENTIFICATION AND CONTROL OF WILDLIFE DAMAGE

Richard A. Dolbeer, Nicholas R. Holler, and Donald W. Hawthorne

INTRODUCTION

Wildlife management often is 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 poisons and traps. Agencies and individuals carrying out control programs are being scrutinized more carefully 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 (1) and (2) to develop an appropriate management program to alleviate or reduce the conflict. Evaluation of control permits an assessment of the reduction in damage in relation to costs and impact of the control on target and nontarget populations. Increasingly, emphasis is being placed on integrated pest management whereby several control methods are used in combination and coordinated with other management practices being used at that time (Fig. 1).

This chapter focuses on techniques related to problem definition and methods application. Each major section on groups of wildlife species has three parts—one on assessment of damage; one on identification of damage by individual species; and one on control techniques, which is an elaboration of those listed under each of the species.

LEGAL REQUIREMENTS FOR CONTROL

Capturing or Killing Wildlife Species

Before action is taken to control wildlife damage, it is important to understand the laws covering the target wildlife species. The management of most wild mammals, reptiles, and amphibians in the United States and Canada is the responsibility of the individual states and provinces. The capture, possession, or killing of these vertebrates to achieve control of damage or nuisance situations is regulated by state or provincial laws. The main exception for

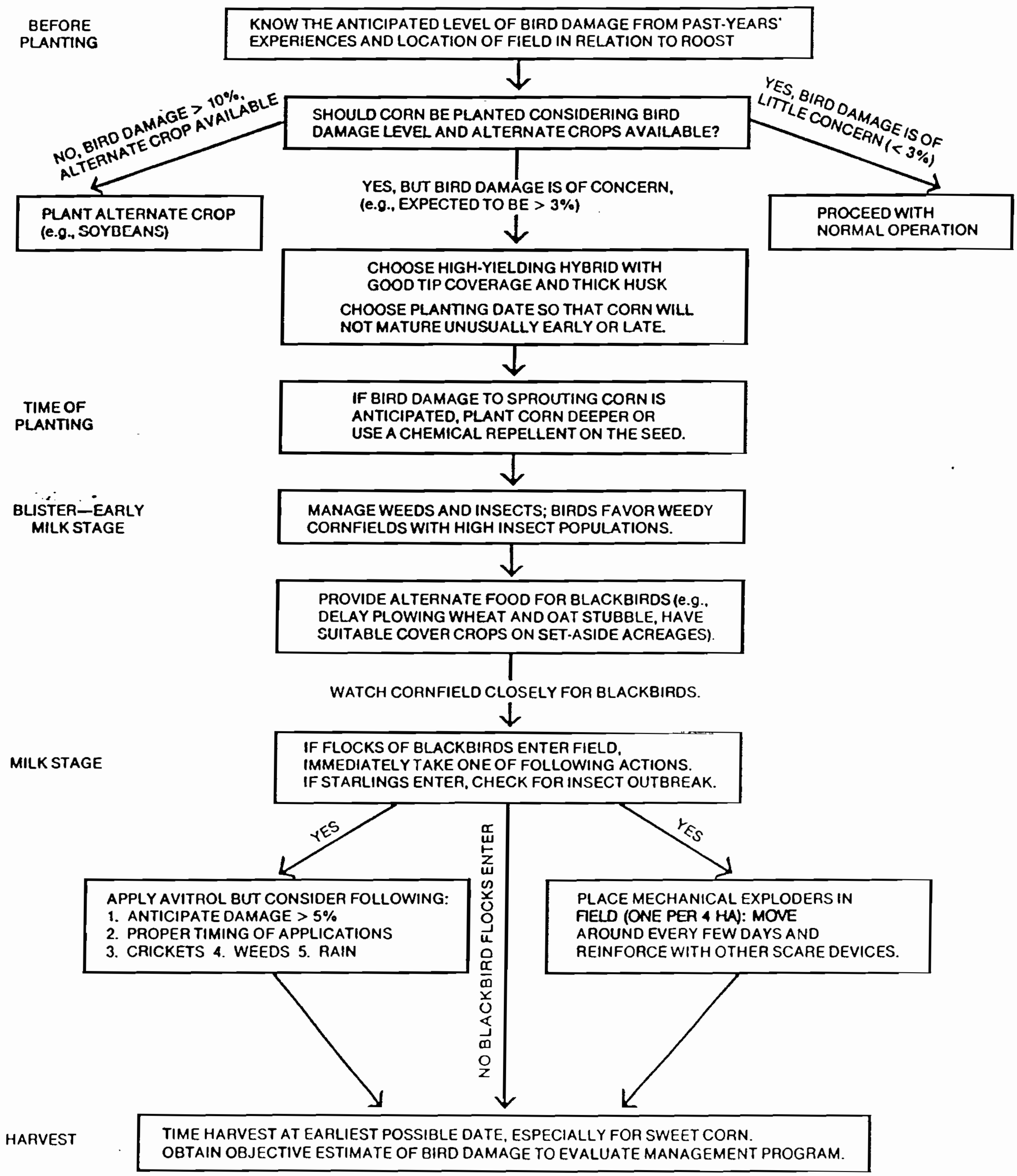

Fig. 1. Schematic chart of integrated management program on farm to reduce blackbird damage to corn (from Dolbeer 1980).

mammals, reptiles, and amphibians in the United States regards endangered species that are regulated at the federal level by the Endangered Species Act of 1973, as amended.

Migratory birds, in contrast to these other vertebrates, are managed in North America at the federal level under the Migratory Bird Treaty Act of 1918, a treaty that has been amended several times and includes formal agreements with Canada, Mexico, Japan, and the Soviet Union (see Chapter 17). Federal regulations in the United States and Canada require that a depredation permit be obtained from the U.S. Fish and Wildlife Service and Canadian Wildlife Service, respectively, before any person may capture, kill, possess, or transport most migratory birds to control depredations. No federal permit is required merely to scare or herd depredating birds other than endangered or threatened species, or bald or golden eagles.

Introduced avian species in the United States such as house sparrows, pigeons, starlings, and monk parakeets have no federal protection. Furthermore, a federal permit is not required to control yellow-headed, red-winged, tricolored, rusty, and Brewer's blackbirds, cowbirds, all grackles, crows, and magpies when they are found committing or about to commit depredations upon ornamental or shade trees, agricultural crops, livestock, or wildlife or when they are concentrated in such numbers and manner as to constitute a health hazard. However, federal provisions do not circumvent any state laws or regulations which may be more, but not less, restrictive.

In summary, anyone contemplating the capture or killing of a vertebrate species for damage control must first determine the state or provincial regulations for that species. For birds and endangered species, federal regulations also must be followed.

EPA Registration of Chemicals

The Federal Insecticide, Fungicide, and Rodenticide Act (FIFRA), as amended, requires all pesticides and other chemicals used in controlling or repelling organisms in the U.S. to be approved and registered by the Environmental Protection Agency (EPA). The registration process has become increasingly complex and costly, not only for new products being introduced but also for previously registered products being reviewed and re-evaluated (Hood 1978, Goldman 1988). Products federally registered for nationwide use under Section 3 of FIFRA may not be available for use in all states in the U.S., because many states have their own registration requirements that might be more restrictive. Some products have Section 24C registrations that are valid only for specific states that have localized problems. Occasionally, products are available temporarily in specific localities for emergency use under Section 18 provisions of FIFRA. Finally, many of the registered compounds, such as vertebrate toxicants, are classified as "restricted use" pesticides. These products can be used only by, or under the direct supervision of, a certified pesticide applicator. Each state has its own certification requirements. Thus, anyone contemplating use of chemicals in wildlife damage control must determine the status of and requirements for use of those chemicals in their particular locality. Jacobs (1993) provided a comprehensive list of registered chemicals for wildlife damage control.

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 of 272,154 metric tons worth $31 million in the United States (Besser and Brady 1986). Blackbird damage to sunflowers 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 U.S. 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 the damage is usually conspicuous. For these reasons, subjective estimates often overestimate losses as much as 10-fold (Weatherhead et al. 1982). Thus, objective estimates of bird damage to agricultural crops are important to accurately define the magnitude of the problem and to plan appropriate, cost-effective control actions (Dolbeer 1981).

To estimate losses 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 300 m long, the estimator might walk staggered distances of 30 m along 10 randomly selected rows (e.g., 0–30 m in row 9, 31–60 m in row 20, and so on). In each 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 hectare. 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 percentage of the agricultural 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 (Weatherhead et al. 1982, White et al. 1985).

Species Damage Identification

Most bird damage occurs during daylight hours, and the best way to identify the species causing damage is by observation. Presence of a bird species in a crop 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%/year since the early 1970s (Blokpoel and Tessier 1986). 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 and at aquaculture facilities, eat duck eggs and kill ducklings, and compete with threatened bird species for nest sites.

Control Techniques.—Habitat manipulation, screening and wire grids, mechanical and chemical frightening agents, toxicants, shooting.

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, sunflowers, and rice can be serious (Dolbeer 1993). 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 (Fig. 2). Blackbird damage to sprouting rice in the spring can be serious in localized areas.

Starling depredations at feedlots in winter can cause substantial losses (Besser et al. 1968, Glahn et al. 1983). 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 seriously damage 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, and roost sites, if used for several years, can become focal points for the fungus that causes histoplasmosis, a respiratory disease in humans.

Control Techniques.—Habitat manipulation, cultural practices (e.g., resistant crop varieties), proofing and screening, mechanical and chemical frightening agents, repellents, toxicants, trapping, shooting, roost treatment with wetting agent (PA-14).

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). Of particular concern, droppings that are allowed to accumulate over several years may harbor spores

Fig. 2. Damage to corn by blackbirds (top) and raccoons (bottom) can sometimes be confused. Blackbirds usually slit the husk and peck out the soft contents of kernels, leaving the pericarp. Raccoons and squirrels chew through the husk and bite off the kernels (photo, R. A. Dolbeer).

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.

Control Techniques.—Screening and proofing, overhead wires, trapping, toxic and stupefying (alpha-chloralose) baits, shooting, and toxic perches.

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 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.

Control Techniques.—Mechanical frightening devices, shooting, trapping, chemical frightening agents, toxicants.

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 U.S. have sustained heavy depredation by cormorants. In recent years double-crested cormorants have caused serious losses at commercial fish ponds in the southern U.S. (Stickley and Andrews 1989). Nighttime observations are sometimes necessary to determine the depredating species, because herons and bitterns will feed at night.

Control Techniques.—Habitat modification, screening, overhead wires, frightening devices, shooting.

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 1993). 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 that have small amounts of tissue clinging to their bases were pulled from a cold bird that 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 generally will solve a problem.

Control Techniques.—Proofing and screening, habitat modifications, frightening devices, trapping and transplanting, shooting.

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 through 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 2.5–5.0 cm apart in a straight line or small "V", and the wound from the hallux will be 10–15 cm from that of 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 tissue between the talon punctures is seldom crushed. If a puncture cannot be seen from the outside, skinning the carcass will reveal 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 punctures from the three opposing talons in the base of the skull or top of the neck (O'Gara 1978, 1993).

Control Techniques.—Modified herding techniques, mechanical frightening devices, trapping and transplanting, shooting.

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.

Control Techniques.—Exclusion, sticky repellents, live traps, snap traps, shooting, frightening devices.

DUCKS, GEESE, AND SANDHILL CRANES

Damage by ducks and cranes to swathed or maturing small-grain crops during the autumn 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 grazing on winter wheat and rye crops can reduce subsequent grain and vegetative yields (Kahl and Samson 1984, Conover 1988). Canada geese also can be a serious problem to sprouting soybeans in spring and in fields of standing corn in 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).

Control Techniques.—Mechanical frightening devices, lure crops, hunting, trapping and transplanting, overhead wires, capture with drug (alpha-chloralose).

Control Techniques

MODIFICATIONS OF HABITAT AND CULTURAL PRACTICES

Habitat and cultural modifications can be implemented in many situations to make roosting, loafing, or feeding sites less attractive to birds. Although the initial investment of time and money may be high, these modifications often provide long-lasting relief. Thinning or pruning vegetation can cause roosting birds such as starlings to move, often increasing the commercial or aesthetic value of the trees at the same time (Good and Johnson 1978, Micacchion and Townsend 1983). Gull activity at airports can be reduced by eliminating standing water, allowing grass along runways to grow to 15 cm, and prohibiting landfills in close proximity. The U.S. Federal Aviation Administration's policy is that solid-waste disposal sites should not be located within 3 km of any runway used by turbine-powered aircraft (Harrison 1984).

The use of lure crops, where waterfowl or blackbirds are encouraged to feed, is sometimes cost-effective in reducing damage to nearby commercial fields of grain and sunflowers where bird-frightening programs are in place (Sugden 1976, Cummings et al. 1987). Bird-resistant cultivars of corn, sunflower, and sorghum have shown effectiveness in reducing damage. For example, cultivars of sweet corn with ears having long, thick husks difficult for blackbirds to penetrate have less damage than do cultivars with ears having short, thin husks (Dolbeer et al. 1988*b*). Planting crops so that they do not mature unusually early or late also can reduce damage by blackbirds (Bridgeland and Caslick 1983). Control of insects in cornfields can make those fields less attractive to blackbirds and reduce subsequent damage to the corn crop (Woronecki et al. 1981).

PROOFING AND SCREENING

Nylon or plastic netting is cost-effective in excluding birds from individual fruit trees or high-value crops such as blueberries or grapes (Fuller-Perrine and Tobin 1993) (Fig. 3). Netting or wire screening can be used to exclude birds from rafter areas of airport hangars, undersides of bridges, fish hatcheries, and vent openings of buildings. Ledges on buildings can be covered with slanting boards or other material placed at a 45° angle to prevent bird perching or nesting. Electrically charged wires installed on ledges and other sites can prevent birds from perching.

Parallel strands of monofilament lines or wires strung at 2.5- to 12-m intervals over ponds, landfills, and other structures can reduce gull activity (Blokpoel and Tessier 1984, McLaren et al. 1984). Monofilament lines at 30-cm to 60-cm intervals repelled house sparrows from feeding sites (Agüero et al. 1991). Gulls and house sparrows are reluctant to fly through these strands even though the spacing is larger than their wingspans. Overhead lines also have excluded birds from fish hatcheries. Recommended spacing between wires is 60 cm for mergansers and 30 cm for great blue herons (Salmon and Conte 1981). Heavy plastic (PVC) strips hung from open doorways will help exclude starlings and other birds from buildings (Johnson and Glahn 1993).

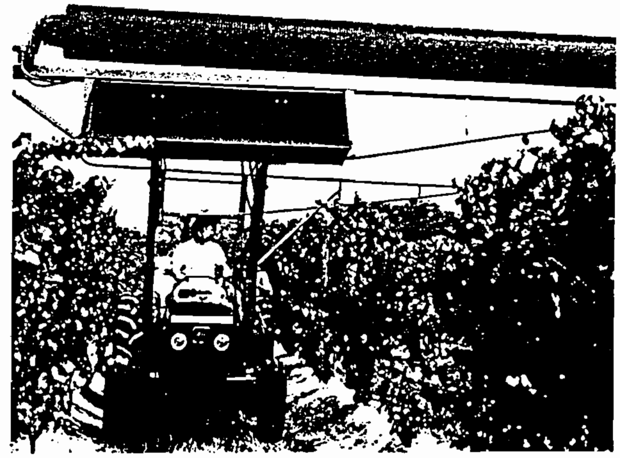

Fig. 3. Nylon netting can be a cost-effective means of eliminating bird damage from high-value crops such as in this vineyard on Long Island, New York (photo, M. E. Tobin).

FRIGHTENING

Mechanical Devices

Many devices are marketed, or homemade, to frighten birds. Birds usually habituate to such devices, no matter how effective they may be initially. Thus, two important rules are: (1) never rely solely on one type of device for frightening, and (2) vary the use of devices by altering the timing and location. Frightening devices are only as effective as the person deploying them.

Probably the most widely used frightening device is the propane cannon (Fig. 4), which produces a loud explosion at timed intervals. Several models are marketed, including ones with automatic timers and rotating barrels. To be effective in frightening birds from crops, at least one cannon should be used for each 2 ha and the cannons should be moved every few days. An occasional shotgun patrol to reinforce the exploders is important (Dolbeer 1980), using either live ammunition or shell crackers. Shell crackers, fired from a 12-gauge shotgun, shoot a projectile that explodes 50–75 m away. Other pyrotechnic devices for frightening birds include rockets and whistle bombs (Booth 1993).

Recorded alarm and distress calls of birds broadcast over a speaker system sometimes work well to frighten birds (Bomford and O'Brien 1990). Some airports have speakers mounted on vehicles from which personnel can broadcast these amplified calls for bird species frequently encountered during runway patrols. Shooting at birds with a shotgun often is used to reinforce the distress calls. These calls are commercially available for many bird species (Schmidt and Johnson 1983).

Ultrasonic devices emitting sounds with frequencies above the level of human hearing (20,000 Hz) are marketed for bird control in and around buildings. However, objective field tests have not demonstrated effectiveness of ultrasonic devices in repelling birds (Woronecki 1988). Most birds detect sounds in about the same range of frequencies as do humans.

Flags, helium-filled balloons with and without eyespots, and hawk-kites suspended from balloons or bamboo poles

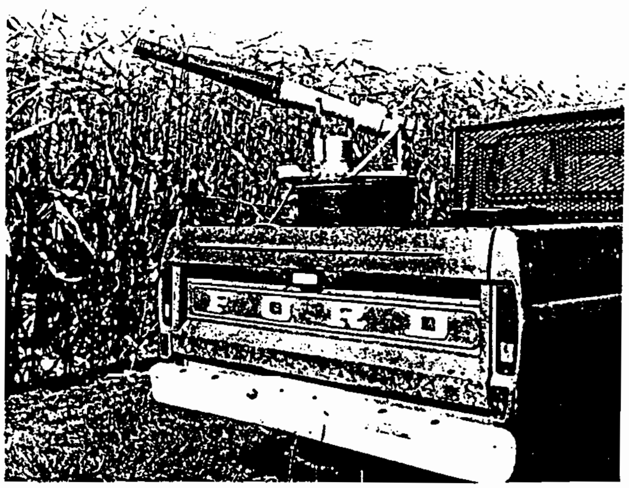

Fig. 4. Propane exploders are often used to frighten birds, especially blackbirds, from corn and other crops. For best results exploders should be elevated above the vegetation, moved around periodically, and occasionally supplemented with a shotgun patrol or other frightening device (photo, R. A. Dolbeer).

have been used with some success to repel birds from various agricultural fields (e.g., Conover 1984*a*). Mylar flags, 15 cm × 1.5 m in size, are used to keep geese from winter wheat, corn, and alfalfa. Ten flags per 4 ha are recommended (Heinrich and Craven 1990). Reflecting tape made of mylar, strung in parallel lines at 3-m to 7-m intervals, has reduced blackbird numbers in agricultural fields (Dolbeer et al. 1986) (Fig. 5).

Blackbird roosts containing up to several million birds can be moved by use of a combination of devices, particularly recorded distress calls, shell crackers, rockets, and propane cannons (Mott 1980). Strobe lights placed in the roost are also helpful. The operation should begin before sunset, when the first birds arrive, and end at dark. People with shotguns and shell crackers should be stationed on the perimeter of the roost to intercept flight lines as they enter the roost. Three to 5 nights of harassment may be required to achieve complete dispersal. If not done as a part of the disposal program, the habitat of the roost should be altered (e.g., tree thinning) after dispersal is achieved to discourage the roost from reforming.

Chemical Agents

Avitrol® is an EPA-registered frightening agent. The active ingredient, 4-aminopyridine, when ingested in small doses, causes the affected bird to emit distress calls while flying in erratic circles. The affected bird usually dies within 0.5 hour, but its initial behavior can act to frighten other birds away. Avitrol is registered for use on pigeons, gulls, house sparrows, starlings, and blackbirds around structures and nesting and roosting sites; for starlings in feedlots; for gulls at airports; and for blackbirds in corn and sunflower fields.

Avitrol-treated bait usually is diluted 1:10 or 1:99 with untreated bait so that only a portion of the birds feeding are affected. For use in standing corn and sunflowers, a 1:99 ratio of treated to untreated cracked corn bait is used. The bait is applied to about one-third of the field at a rate

Fig. 5. Mylar reflecting tape strung above the vegetation can reduce blackbird feeding activity in agricultural fields (photo, R. A. Dolbeer).

of 3 kg/ha when birds first begin to feed in the field. Reapplication may be necessary at 5- to 10-day intervals, depending on rainfall, bird activity, and other factors (Dolbeer 1980).

Alpha-chloralose is a drug that can be mixed with corn or bread baits to immobilize and capture nuisance waterfowl and pigeons. Birds typically become immobilized 30 minutes to 1 hour after ingesting bait and fully recover 4–24 hours later (Woronecki et al. 1992). Alpha-chloralose is restricted by the U.S. Food and Drug Administration for use by U.S. Department of Agriculture biologists in the Animal Damage Control Program.

REPELLENTS

Birds have a poor sense of smell and taste in general, and repellents based on these senses usually are not effective. For example, naphthalene crystals, although registered as an odor repellent for starlings, pigeons, and house sparrows in indoor roosts, have not been effective in field trials (Dolbeer et al. 1988*a*). Taste repellents used as seed treatments to prevent consumption of germinating seeds are also of questionable value (Heisterberg 1983).

In contrast, chemicals that produce illness or adverse physiological response upon ingestion (i.e., conditioned aversion) appear to work well as bird repellents (Rogers 1974). Methiocarb, a carbamate insecticide, is a condition-aversive repellent that has been used as a seed treatment for corn (applied as a powder to the seed at planting) and as a spray treatment for ripening cherries and blueberries.

Several tactile repellents are available to prevent birds from roosting or perching on ledges and other structures. The materials must be placed on clean surfaces. Warm temperatures may cause them to run, and dust reduces their sticky properties (Williams and Corrigan 1993).

TRAPS

Starlings and certain blackbird species often can be captured in decoy traps. A decoy trap is a large (e.g., 6 × 6 × 1.8 m) poultry wire or net enclosure containing 5–20 decoy birds, food, water, and perches (Fig. 6). Birds enter the trap by folding their wings and dropping through an

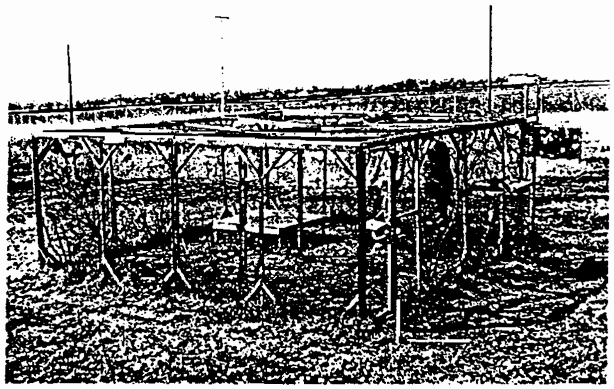

Fig. 6. A typical blackbird and starling decoy trap showing elevated feed platform in center and gathering cage on far right. Birds fold their wings to enter the trap through a 0.6- × 1.2-m opening covered with 5- × 10-cm welded wire located directly above the feed platform (photo, R. A. Dolbeer).

opening (0.6 × 1.2 m) in the cage top covered with 5- × 10-cm welded wire to reach the food (cracked corn, millet) below. Decoy traps have been used to reduce local populations of starlings near cherry orchards (Bogatich 1967), to remove cowbirds from the nesting area of the endangered Kirtland's warbler (Kelly and DeCapita 1982), and to capture blackbirds for banding and research purposes. Pigeons and house sparrows can be captured in various walk-in or funnel traps (Fitzwater 1993, Williams and Corrigan 1993). Mist nets can be used to remove house sparrows around barns and small farm plots (Plesser et al. 1983).

Pole trapping is an effective method for capturing problem hawks and owls because of their preference to perch on tall, isolated poles. A #1½ steel trap with jaws padded with foam rubber or slit surgical tubing is recommended. The trap is placed on an isolated pole near where the killing is occurring. The trap must be rigged to slide down the pole so that the captured raptor can rest on the ground until it is removed for relocation (Fig. 7). The Swedish goshawk trap (Meng 1971) is also useful for capturing problem raptors. Golden eagles preying on livestock can be captured for transplanting with a net gun fired from a helicopter (O'Gara and Getz 1986).

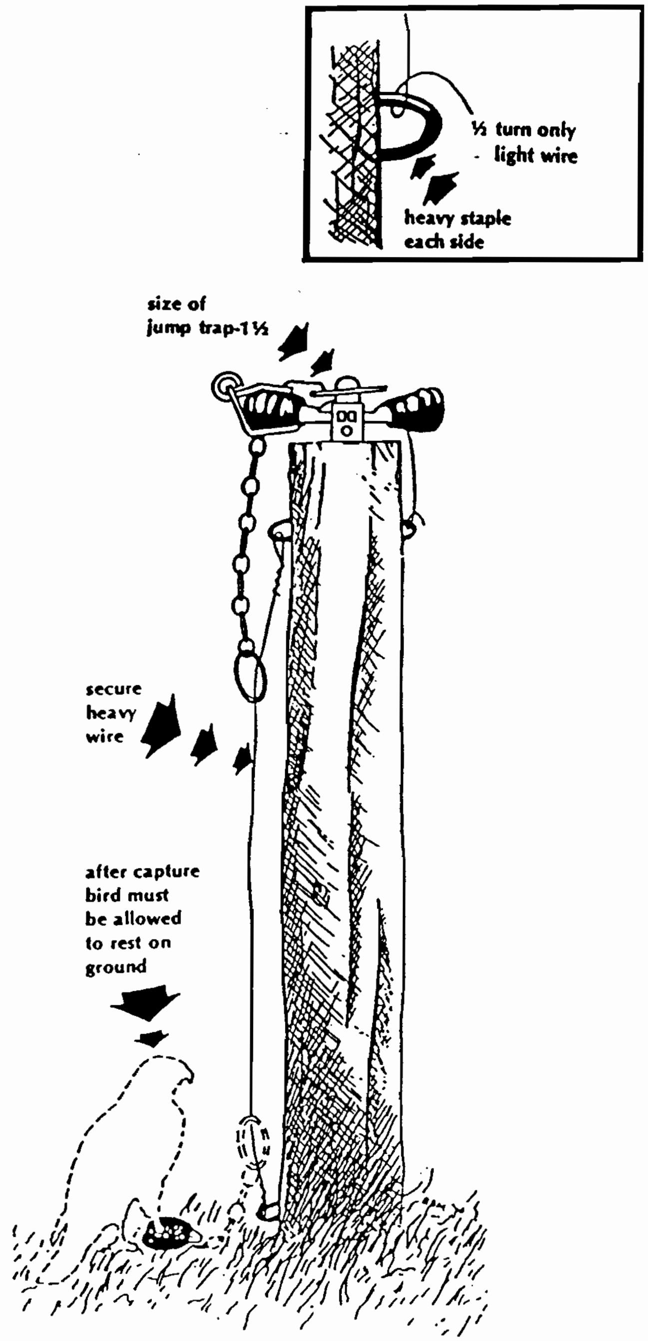

Fig. 7. Pole trap for capturing raptors (from U.S. Department of the Interior 1977).

SHOOTING

Shooting can be effective in reducing local populations of depredating birds if only a few birds are involved. Shooting has little effect on large numbers of birds other than the repelling value (Murton et al. 1974). This concept has been promoted in Wisconsin through a hunter referral program in which farmers allow goose hunters to shoot in agricultural fields sustaining chronic damage (Heinrich and Craven 1987).

The use of .22-caliber bird shot can be effective in removing a few starlings, house sparrows, or pigeons inside buildings, with minimal problems of ricochet or structural damage.

TOXICANTS

The use of toxic baits to kill pest birds without harming nontarget organisms requires patience and a thorough understanding of the habits and food preferences of the target species. Prebaiting for several days with untreated bait is critical, not only to enhance bait acceptance but to assess the amount of toxic bait to be used and possible nontarget hazards. Other nearby sources of preferred food should be restricted as much as possible during the prebait period. Strict control must be maintained over the toxic bait. Dead birds should be collected at least daily and buried.

DRC-1339 is a toxicant incorporated into poultry pellets and marketed as Starlicide Complete® for killing starlings at feedlots and poultry yards. DRC-1339, incorporated into bread baits, also is registered for killing certain gull species that compete with endangered or threatened bird species for nest sites. DRC-1339 affects the renal and circulatory systems, killing the bird 24–72 hours after ingestion. Strychnine-treated whole and cracked corn has been used to kill pigeons and house sparrows, respectively, in and around buildings. However, the EPA has greatly curtailed above-ground uses of strychnine in recent years.

The wetting agent PA-14 is registered by the U.S. Department of Agriculture (USDA) for killing blackbirds and starlings in upland roosts. The material is technically not a toxicant. When mixed with water and applied by aircraft or ground spray systems to roosting birds, the material allows water to penetrate the birds' feathers, cooling the birds so that they die of hypothermia when the air temperature is less than about 10 C (Stickley et al. 1986). The roost site must receive at least 1.3 cm of rain or sprayed water during the night of treatment.

Wick-type perches containing Endrin or Fenthion solution are registered for killing pigeons, sparrows, and starlings in buildings. The material is absorbed through the feet and skin.

UNGULATES

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 values (Scott and Townsend 1985). Browsing of hardwood saplings and young fir trees in regenerating forests can reduce growth rates, misshape trees, and cause plantation failures (Crouch 1976, Tilghman 1989).

Damage to trees caused by antler rubbing can be severe (Scott and Townsend 1985). Small trees (16–25 mm in diameter at 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 $204/ha for orchards, $219/ha for Christmas-tree plantings, and $268/ha in nursery plantings (Scott and Townsend 1985). Losses apparently are in the millions of dollars annually in some U.S. states (Black et al. 1979, Craven 1983, 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 2,680 kg of corn per ha for 51 unprotected cornfields 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).

Species Damage Identification

Ungulates do not have upper 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 1.8 m from a standing position, but are able to reach to 2.5 m by rearing on their hind legs. Elk and moose browse to a height of about 3 m. Deer seldom browse on branches more than 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 1 m high (Pearce 1947).

Control Techniques

HABITAT MODIFICATIONS

Campbell (1974) reported that planting forbs preferred by deer and elk into areas with Douglas-fir seedlings reduced damage to the trees. Nielsen et al. (1982) recommended that trees not preferred by deer for antler rubbing (e.g., sweetgum, pin oaks) be planted in the remote areas of nurseries and highly preferred trees (e.g., plum, cherry) be planted in areas near human activity.

FENCING AND BARRIERS

Many different fence designs have been tested for excluding ungulates. The standard deer fence, a woven wire fence 2.4 m high and topped with barbed wire, is effective but also expensive, costing $4.10/m (Caslick and Decker 1979). Fence designs that use less material include the 1.5-m Penn State Vertical Electric Deer Fence consisting of five strands of high-tensile steel wire (Fig. 8). This design excluded deer in pen trials, whereas four other experimental designs did not (Palmer et al. 1985). Cost was about $0.72 to $1.00/m for materials. Single-strand electric wire fences, 0.6–1 m high and baited with peanut butter to entice deer to contact the wire with their muzzles, have shown effectiveness in reducing damage in orchards and cornfields. The peanut butter was either placed on aluminum foil flags at 10-m intervals or spread continuously on the wire (Porter 1983, Hygnstrom and Craven 1988). Benefit-to-cost ratios were favorable for these baited fences, which cost less than $0.50/m. Electric fences must be monitored routinely and kept clear of vegetation.

Individual seedling protectors made of photo-degradable plastics (e.g., Vexar tubes), as described in RODENTS AND OTHER SMALL MAMMALS [p. 483], are effective in reducing ungulate damage to young conifer trees (Campbell and Evans 1975, DeYoe and Schaap 1983). Individual saplings can be encircled with hardware cloth or chicken wire to prevent browsing or antler rubbing.

REPELLENTS

Numerous odor and taste repellents have been developed to reduce deer browsing on ornamental plants, fruit trees, and crops. High cost and variable effectiveness during the growing season generally make repellents impractical for use on low-value row crops such as corn (Hygnstrom and Craven 1988). Repellents are most effective on trees and shrubs during the dormant season, but results are inconsistent. Even under optimum conditions, some damage occurs.

Conover and Kania (1987) compared human hair, fermented egg solids (BGR®), and a blood meal-peppercorn mixture for reducing deer damage to young apple trees in winter. Trees had either a bag of hair or a bag of blood meal-peppercorns hung from them, or they were sprayed with BGR. All three repellents reduced browsing by about 50%, but whether the benefits would have exceeded costs is questionable.

Other repellents include bone tar oil (Magic Circle®), mothballs, capsaicin (Hot Sauce Animal Repellent®), tankage, the fungicide Thiram (marketed under several trade names), and ammonium soaps of high fatty acids (Hinder®). Results with these products have been mixed (e.g., McAninch et al. 1983, Palmer et al. 1983, Conover 1984*b*, 1987*a*), indicating that factors such as deer numbers, alternate food supply, target plant species, and weather can influence repellent effectiveness.

FRIGHTENING

Propane exploders, flashing lights, shell crackers, and other sonic devices deployed at night can provide temporary relief from ungulate damage. The proper deployment of these devices to maximize effectiveness is discussed in BIRDS [p. 476]. Ungulates adjust to these devices rather quickly, and they are generally not effective for an entire season.

SHOOTING AND TRAPPING

Effective use of the deer hunting season to reduce populations in areas of high damage is one of the best ways to control damage (Craven 1983). Some states also have special depredation permits that can be issued to a landowner to remove a specific number of deer at a problem site outside the normal hunting season if sufficient control cannot be achieved during the hunting season.

Deer can be captured with drop-door traps, rocket nets, or tranquilizer guns (Palmer et al. 1980). However, these methods of deer removal are usually at least twice as expensive as shooting. In addition, one then faces the problems of humanely holding the deer in captivity until they can be transported somewhere for release and finding suitable release sites. In areas such as arboretums, where shooting normally is prohibited, the use of a skilled marksman under permit is probably preferable to live capture (Ishmael and Rongstad 1984). Live capture and transplanting are generally the control option of last resort, mandated by safety or extreme public relations considerations.

RODENTS AND OTHER SMALL MAMMALS

Damage Assessment

Rodents and other small mammals often are not easily observed causing damage, and their damage frequently is difficult to measure and quantify. 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

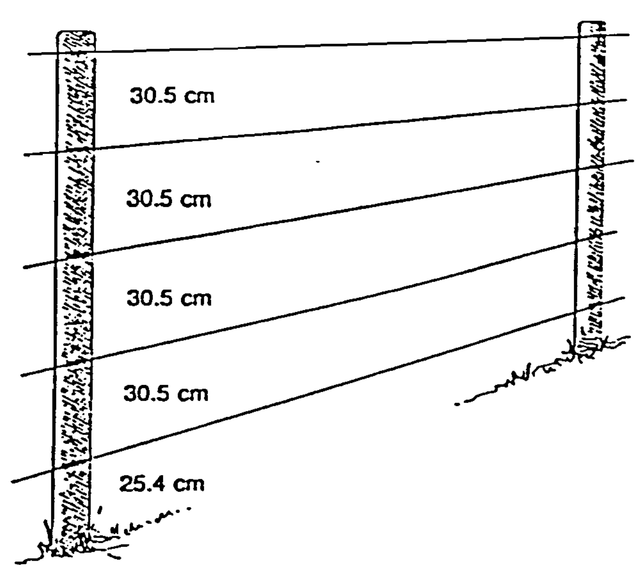

Fig. 8. Two-meter-high Penn State electrified deer fence (from Palmer et al. 1985).

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, caused primarily by beavers, to be $11.2 million on 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 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 ($235/ha) in one-third of the area producing sugarcane in Florida. Losses in Hawaii 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 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*a*).

Pearson and Forshey (1978) compared yield 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 percentage of stalks damaged (Lefebvre et al. 1978). Clark and Young (1986) established transects in cornfields 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 cost/benefit evaluation of control programs. This conversion is difficult, given the vast areas involved and the variability in rodent populations.

In some situations (e.g., timber flooded by beavers, 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 (e.g., bat colonies 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.

Species Damage Identification

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

Characteristics of the damage also may provide clues to the species involved. In orchards, for example, major stripping of roots usually is caused by pine voles, whereas damage at the root collar or on the trunk up to the extent of snow depth most often is 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 be grouped generally as follows: root damage—pocket gophers and pine voles; trunk debarking—meadow voles, squirrels, porcupines, woodrats, rabbits, and mountain beavers; stem and branch cutting—beavers, rabbits, meadow voles, mountain beavers, pocket gophers, woodrats, 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 sign (e.g., tracks) or by capture of individuals.

ARMADILLOS

The armadillo has extended its range eastward and northward from Texas and now is found in all Gulf 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 this 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 1982). 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).

Control Techniques.—Exclusion fencing (25-cm-high poultry mesh), habitat manipulation (removal of cover), reduction of food through use of insecticides, live traps with wing fencing, conibear traps, leg-hold traps, shooting.

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: little brown bat, big brown bat, Brazilian 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 laws. 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 usually is evidenced by noise (squeaking, scratching) and by the presence and distinctive, pungent odor of the accumulated fecal droppings and urine. Bat feces are readily identified 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). Where bat colonies are allowed to persist so that guano deposits accumulate, the fungus that causes histoplasmosis can develop. Bats roosting near airports may be hazardous to aircraft (Kincaid 1975).

Control Techniques.—Exclusion (including the use of valve devices that permit bats to leave but not return; this should be done after young reach flight stage), repellents, traps, artificial roosts, education to overcome phobias, toxicants (may increase risk of exposure to rabies and is not recommended in most situations).

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, green sticks with the bark freshly peeled off may be found when beavers are active in an area.

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 (Fig. 9) is of much greater importance, however, especially in the southeastern U.S. where beaver populations have increased dramatically as a result of a decline in trapping due to low pelt prices (Woodward 1983). Beavers often use sticks to plug road culverts or water-control structures in ponds and reservoirs. Additionally, beavers can cause extensive damage to levies 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).

Control Techniques.—Conibear traps, snares, leg-hold traps (#3 or larger), basket/suitcase-type live traps, shooting, explosives for dams, habitat manipulation, drain devices in dams or culverts.

Fig. 9. **Damage to timber by beaver can be extensive in lowland areas where their activities result in permanent flooding of large areas (photo, F. Boyd, USDA/APHIS).**

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 1982). In parts of the western U.S., chipmunks are a potential reservoir for plague and are controlled in campgrounds (Marsh and Howard 1982). Chipmunks are easily observed due to their diurnal activity; their presence also can be determined by trapping.

Control Techniques.—Snap traps, live traps, toxic baits, repellents, shooting (.22-caliber with bird shot, shotgun, or air rifle), exclusion.

COTTON RATS

The hispid cotton rat, a common species in southern U.S. and Mexico, is the species of cotton rat most often causing damage. Two other species have localized occurrences in Arizona and New Mexico. They undergo major population fluctuations. Cotton rats are primarily vegetarian, but they also prey on eggs and young of ground-nesting birds (Hawthorne 1993). 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 observed often. Their presence also is indicated by well-developed runways through dense vegetation and the presence of grass cuttings 5–8 cm long placed in piles. Pale greenish-yellow droppings, about 9 mm long and 5 mm wide, sometimes are present in the runway. Cotton rat sign is similar to that of voles, but droppings, runways, and clippings of the cotton rat usually are larger (Hawthorne 1993). Cotton rats are often one of several rodent species causing damage in crops.

Control Techniques.—Habitat modification, toxic baits, snap traps.

PEROMYSCUS *(DEER MICE, WHITE-FOOTED MICE)*

The genus *Peromyscus* is large, and one or more species are 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 seedings in conservation tillage systems, but this damage may be offset by their consumption of harmful insects and weed seeds (Clark and Young 1986, Johnson 1986). *Peromyscus* invade homes where they eat stored food and damage upholstered furniture or other materials shredded for use in nest building. Trapping with snap or live traps is the best method to determine the species present.

Control Techniques.—Habitat modification, provision of alternative foods (Sullivan and Sullivan 1982), exclusion, snap traps, live traps, toxic baits, repellents.

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. Ground squirrels are an important predator of waterfowl eggs in the prairie pothole region (Sargeant and Arnold 1984). They carry several diseases transmissible to man, including plague; in plague-endemic areas, ground squirrel control should be combined with ectoparasite control (Marsh and Howard 1982).

Ground squirrels are diurnal and easily observed (Marsh 1985*a*). They hibernate and estivate and have ma-

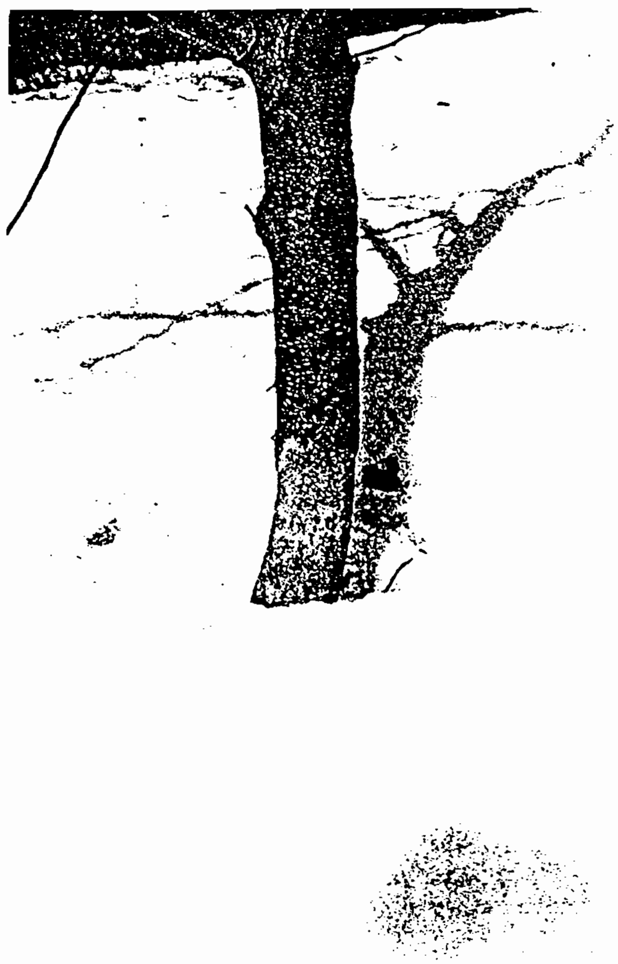

Fig. 10. Meadow voles cause reduced apple production and sometimes loss of trees in orchards where they tunnel through snow and girdle trees by gnawing bark near the root collar and up the trunk as far as snow cover extends (photo by M. E. Tobin).

jor dietary shifts during the year (Marsh 1985*a*, 1986). Effective control strategies must consider these factors.

Control Techniques.—Habitat manipulation, toxic baits, live traps, leg-hold traps (#0–1½), snap traps, fumigants, exclusion, shooting.

KANGAROO RATS

Kangaroo rats are competitors of livestock on arid western rangelands (Marsh 1985*a*) when present in high populations, especially during drought. They also can retard recovery of overgrazed rangelands when cattle are removed (Howard 1993) and spread undesirable shrub species by caching of seeds (Reynolds and Glendening 1949, Marsh 1985*a*). Kangaroo rats cause significant damage to alfalfa and corn on irrigated sandy soils by consuming newly planted seeds and clipping off seedlings (Howard 1993). Sorghum, other grains, and garden crops also can be damaged in local areas.

Several species of kangaroo rats are endangered. Kangaroo rats are nocturnal, but their burrow systems, with above-ground 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.

Control Techniques.—Habitat manipulation, snap traps, live traps, toxic bait, exclusion from small areas, provision of alternate food.

MARMOTS

Marmots (woodchucks), like ground squirrels, can cause damage to many crops; forage production may be reduced markedly by marmot feeding and trampling (Marsh 1985*a*). They damage fruit trees and ornamental shrubs by gnawing or scratching woody vegetation (Bollengier 1993). 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 1982). 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.

Control Techniques.—Fumigants, shooting, conibear traps, leg-hold traps (#1½–2), live traps.

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*a*, Pauls 1986, Sullivan et al. 1987, O'Brien 1993). 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 6 mm in diameter (Fig. 10). Some species (e.g., 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 also can damage field and garden crops; when vole populations are high, these losses can be catastrophic (Clark 1984, Marsh 1985*a*). Voles are carriers of bubonic plague and tularemia.

Vole populations are subject to large, rapid fluctuations. The presence of voles is determined most easily 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 3 mm wide, 2 mm deep, and 10 mm long. In hay crops, runways with numerous burrow openings, clipped vegetation, and feces can be detected in dense vegetation.

Control Techniques.—Screening, plastic mesh protectors for seedlings (Pauls 1986), habitat modification, toxic baits, snap traps (for small populations in local situations), provision of alternative foods (Sullivan and Sullivan 1988).

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 also use the burrows of moles and can be responsible for some damage attributed to moles (Henderson 1993). Burrowing by moles may reduce production of forage crops by undermining and smothering vegetation and by exposing root systems to drying. Their surface burrows also can 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 usually can 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 mounds can be distinguished from those of pocket gophers by their more rounded contour and the lack of a burrow entrance or soil plug (Eadie 1954).

Control Techniques.—Harpoon, scissors, and choker traps; habitat manipulation (e.g., soil compaction); toxic bait; fumigants; repellents (thiram for protection of bulbs); insecticides (for removal of food source).

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 12–15 years (Evans 1987*a*). Mountain beavers clip seedlings and gnaw saplings and the stems and bark of larger trees.

Mountain beavers normally clip through seedlings at a 45° angle. On small seedlings this clipping may be difficult to distinguish from rabbit damage; however, rabbits seldom clip stems larger than 6 mm in diameter or 50 cm above ground level, whereas mountain beavers often cut stems larger than 13 mm in diameter and up to 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.

Control Techniques.–Conibear (#110) traps, live traps, leg-hold traps (#1½–2), toxic bait, plastic mesh tree protectors, habitat manipulation.

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 vegetarian, but they will feed on aquatic animals if vegetation is limited (Miller 1993).

Muskrats commonly construct cone-shaped houses projecting 0.5–1 m 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 drawdown of ponds or reservoirs (Miller 1993).

Control Techniques.—Conibear traps, leg-hold traps (#1–2), stovepipe traps, toxic baits, exclusion (specialized dam construction techniques [Miller 1993]), habitat manipulation.

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 1993). Nutria may severely impede baldcypress 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.

Control Techniques.—Habitat manipulation, toxic baits (most effective on floating bait stations [LeBlanc 1993]), leg-hold traps (#2), conibear traps (#210), shooting.

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 also may damage plastic irrigation lines on agricultural lands as well as underground pipes and cables in other situations.

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*a*). They can greatly reduce the carrying capacity of rangeland for livestock. Gophers can be a serious pest in alfalfa by feeding on the leaves, stems, and roots (Marsh 1985*a*). Gopher mounds can cause equipment breakage and increased wearing rate of haying machinery. Gopher tunnels result in water loss in irrigated areas (Case and Jasch 1993).

Pocket gophers are a major impediment to reforestation in the western U.S. (Crouch 1986). During winter they often forage above ground by tunneling in the snow. Coniferous trees have been debarked to a height of 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 inflicted by meadow voles. Gophers sometimes pull saplings and vegetation into the burrow.

Control Techniques.—Toxic baits, lethal traps (Macabee, Victor, or California pocket gopher traps), fumigants, habitat modification (flood irrigation, crop rotation), seedling protection (plastic mesh), protective coverings for pipes and cables.

PORCUPINES

Porcupines are usually nocturnal and are active all year. During summer, they often feed on succulent plants, including garden and truck crops, in open meadows, in 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 1982). Girdling in the upper bole 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 exposed sapwood. Abundant oblong droppings about 2.5 cm long can be found under freshly damaged trees. Clipped twigs and tracks also may be found on snow. Top girdling in pines produces trees with a characteristic brushy crown.

Control Techniques.—Shooting, leg-hold traps (#1–3), proofing and screening (small areas or individual trees).

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 40 million ha. By 1971, following intensive control efforts, only 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 1993). 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 bubonic plague (Hygnstrom and Virchow 1993).

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.

Control Techniques.—Toxic grain bait, fumigants, shooting, leg-hold traps (#0–2), conibear traps (#120), habitat modification (deferred grazing).

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 1993).

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).

Jack rabbits 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). Jack rabbit 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 6 mm in diameter or less at a height not more than 50 cm above the ground (Lawrence et al. 1961). Repeated clipping will deform seedlings. Rabbits and hares often can be observed at damage sites along with their tracks, trails, and droppings.

Control Techniques.—Habitat modification, fencing and proofing, repellents, live traps, body snares, shooting, toxic baits for jack rabbits in some localities.

TREE SQUIRRELS

Tree squirrels can be categorized into three groups: large tree squirrels (gray, fox, and tassel-eared), pine squirrels (red and Douglas'), and flying squirrels (northern and southern) (Jackson 1993). Squirrels eat plants and fruits, dig up newly planted bulbs and seeds, strip bark and leaves from trees and shrubs, invade homes, and consume bird eggs (Hadidian et al. 1987, Jackson 1993). They cause problems by shorting out transformers and gnawing on power and telephone lines (Marsh and Howard 1982, Hamilton et al. 1987).

Squirrels often can be observed at the damage site. Damage to conifer seeds 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 often are found on the ground, as are the tips of twigs and small branches.

Control Techniques.—Fencing and proofing, repellents, live traps, shooting, conibear traps, leg-hold traps (#0–1), toxicants.

WOODRATS

Woodrats, 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, in abandoned vehicles, or in the upper branches of trees (Marsh and Howard 1982, Salmon and Gorenzel 1993). They will shred mattresses and upholstery.

Woodrats 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 also will clip small branches. Their damage may be confused with that of tree squirrels and porcupines; however, woodrats 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 woodrats are endangered. Local regulations should be checked before control efforts are undertaken.

Control Techniques.—Exclusion, repellents (mothballs have questionable efficacy), toxic baits, snap traps, live traps, shooting.

Fig. 11. Rats damage sugarcane by gnawing internodal areas of stalks, creating canoe-shaped damage areas. This damage results in death of some stalks and loss of production in damaged stalks that survive (photo courtesy of Denver Wildl. Res. Cent., USDA/APHIS).

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 25–150 pellets and void 10–20 cc of urine every 24 hours, and constantly shed fine hairs.

Rats cause extensive damage to sugarcane in Hawaii and Florida (Fig. 11), and roof rats are serious pests in Hawaiian macadamia nut plantations. These rodents will feed on poultry chicks and occasionally will 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.

Gnawing by rodents causes considerable property damage. Fires are sometimes started when rats and mice gnaw the insulation of electric wiring. They also will 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 sometimes results 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 were provided by Meehan (1984), Jackson (1987), Baker et al. (1993), Marsh (1993), and Timm (1993).

Control Techniques.—Habitat modification, proofing and screening, snap traps, toxic baits (multiple dose and acute), tracking powder, fumigants.

Control Techniques

MODIFICATIONS OF HABITAT AND CULTURAL PRACTICES

All animals are dependent on food and shelter; therefore, elimination of one or both of these requirements will force them to move from the immediate area. This method of control, where practical, is often the most desirable and usually has the most permanent effect in stopping small mammal damage. One should recognize, however, that other species often are dependent upon the habitat being modified. Modifications of the habitat can result in greater adverse impacts to desirable nontarget species and natural communities than would careful use of a registered toxicant or other control tool. They also can create situations that result in other species becoming pests.

Many rodents and small mammals can be discouraged from using areas by removal of brush piles, weeds, old lumber piles, and other debris. Commensal rodent control can be greatly facilitated by removal of harborage, garbage, and refuse (Jackson 1987). Squirrel interference with power transformers may be reduced if vegetation near power poles is managed (Hamilton et al. 1987). Mountain beaver populations in cultivated areas may be decreased by removing surface shelters such as stumps, logs, and brush piles (Eadie 1954). High populations of round-tailed muskrats in Florida sugarcane are associated with trash remaining in fields after harvest (Steffen et al. 1981).

Control of pine voles with anticoagulant baits was enhanced in apple orchards cultivated two or three times a year (Byers 1976). Davis (1976) reported that pine vole damage in an apple orchard was reduced by mowing three times a year, clearing vegetation from under the trees, removing pruned branches, restricting the distribution of fertilizer, and, after harvest, inspecting and cleaning vulnerable parts of the orchard. Byers (1984*b*), however, observed that cultural controls (combinations of mowing, cultivation, and herbicide application) were much more expensive than the use of toxic baits and offered no advantages in vole control.

Provision of alternative foods will reduce conifer seed loss to mice in forest regeneration projects (Sullivan and Sullivan 1982) and also might be useful in reducing loss of corn seedlings in no-tillage fields (Johnson 1986). A study in British Columbia indicated that provision of alternate foods might reduce vole damage in apple orchards (Sullivan and Sullivan 1988). Pocket gopher infestations in logged areas can be reduced by prompt regeneration

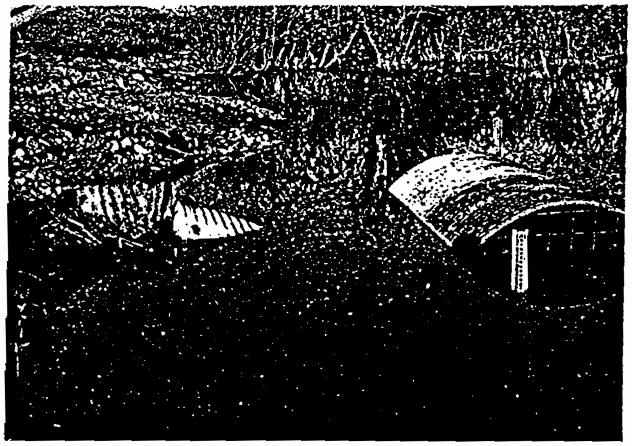

Fig. 12. Mechanical devices, such as these T-culverts developed in New York, may be used to prevent beavers from stopping water flow through culverts (photo, K. Roblee, N.Y. State Div. Fish Wildl.).

and minimal site preparation. Selective cutting, when feasible, can be used in areas with a high potential for gopher infestations (Crouch 1986). The use of insecticides to reduce soil invertebrates can protect turf from armadillos and moles, but damage may increase initially because of increased food searching by animals already present (Henderson 1993).

Water levels behind beaver dams can be manipulated by installing a perforated pipe (Laramie 1978) or a three-log drain (Miller and Yarrow 1993) through the dam. Various mechanical methods have been developed to prevent beavers from stopping water flow through culverts (Roblee 1987) (Fig. 12). Muskrat damage to farm pond dams can be reduced by maintaining a 3:1 slope on the water side of the dam, a 2:1 slope on the outer face, and a top width ≥2.4 m (Miller 1993). The water level should be maintained at least 0.9 m below the top of the dam.

EXCLUSION

Exclusion involves the placement of barriers that prevent access by pest species into structures or areas, or their physical contact with specific objects. Proofing of structures is achieved most economically if it is considered prior to construction. Baker et al. (1993) provided detailed suggestions of ways to accomplish rodent-proof construction. Basically all openings or sites where rodents might create openings are protected with wire mesh, sheet metal, or concrete, providing long-term protection.

Exclusion is a necessary part of an effective program to remove bats from structures. Final closing of entrances to the structure should not be made until all young have reached the flight stage. At that time these openings can be closed with a valve device that permits bats to leave the structure but prohibits reentry (Greenhall 1982, Frantz 1986).

In small orchards, rabbit and rodent damage can be eliminated by wrapping trees with hardware cloth or burlap that is buried about 5 cm deep around the tree base. In England, wire netting and electrified netting fences have been effective in excluding rabbits from crop fields (McKillop and Wilson 1987). Fences made of 1.2- to 2.5-cm-mesh net wire 0.7–1 m high can protect small areas against nonclimbing rodents and small mammals. Fences should be buried 15 cm deep with an "L" shape on the outside of the fence.

A 0.6-m-wide expandable metal band placed around tree trunks 2 m above the ground will keep squirrels out of isolated trees. Branches should be trimmed within 2 m of the ground or buildings. Steel-sheathed wire may be used on underground power and telephone lines to prevent pocket gopher gnawing. VEXAR® plastic seedling protectors or Remay sleeve protectors will protect conifer seedlings from pocket gophers, mountain beavers, and lagomorphs (Anthony et al. 1978, Evans 1987*a*). These plastic net-tubes, 76–90 cm tall and 5 cm in diameter, are placed over seedlings at planting. They allow branches to grow through the netting and provide protection for the terminal bud for about 3–5 years as it grows up through the tube. The protectors photodegrade.

FUMIGANTS

Fumigants produce gases that are lethal when inhaled; they are used to kill various burrowing mammals such as pocket gophers, commensal rodents, prairie dogs, ground squirrels, chipmunks, and woodchucks. When fumigants are used, all burrow openings should be closed after introduction of the pesticide. Gas cartridges are incendiary fumigants that produce carbon monoxide, causing death by suffocation (Dolbeer et al. 1991). Aluminum phosphide is a fumigant available in tablets or pellets that produces toxic phosphine gas when in contact with atmospheric moisture; this gas is flammable or explosive at some concentrations. Calcium cyanide is a fumigant that in the presence of moisture releases hydrocyanic acid (HCN), a colorless gas that is highly toxic by contact, ingestion, or inhalation. Calcium cyanide is extremely dangerous, requiring extra caution in its use. Amyl nitrite, an antidote, should always be immediately available when this fumigant is used. Some other registered fumigants are carbon disulfide, chloropicrin, magnesium phosphide, and methyl bromide. Jacobs (1993) provided information on specific fumigants.

TOXICANTS

Toxicants often are used to control damage by rodents and other small mammals. Efficacy of toxicant formulation and potential hazards to nontarget species must be considered when toxicants are used. Damage reduction is the goal of any control program, and this must be the final measure of efficacy. Efficacy of a control program sometimes can be increased by using several toxicants in combination or by periodically alternating those used; this can aid in overcoming developed resistance of the pest species to the primary toxicant (Marsh 1988*a*).

Hazards associated with the use of a toxicant are not necessarily related to the toxicity of the compound. They are associated more often with the use pattern. Hazards to nontarget wildlife can be reduced by properly selecting rodenticides, bait composition and formulation techniques (including bait color, size, shape, texture, and hardness), and bait delivery systems (Marsh 1985*b*).

Toxicants can best be discussed as anticoagulants and non-anticoagulants. Previously, anticoagulants were referred to as multidose or chronic toxicants and non-anticoagulants as single-dose or acute toxicants. New-generation anticoagulants, however, can be effective in a single feeding, and some new non-anticoagulants can be ingested by individuals of the target species over several days (Marsh 1988*a*).

Numerous rodenticide formulations are registered for use in commensal rodent control, around farm buildings, and in noncrop areas. Few rodenticides are registered for in-crop use, although such use may be necessary to achieve adequate control of damage (Lefebvre et al. 1985*a*). Development of registrations for in-crop use of rodenticides, particularly anticoagulants, is a high priority area for research.

Anticoagulants

Anticoagulant toxicants inhibit blood coagulation and result in internal bleeding leading to death (Meehan 1984). Early anticoagulants such as warfarin, pindone, diphacinone, and chlorophacinone generally require ingestion for 3–14 consecutive days to be effective. Bait shyness generally is not a problem because the animals do not associate ill effects with bait consumption. However, bait delivery procedures must consider the need for making toxicants available over a continuous period of days. Two of the newer anticoagulants, brodifacoum and bromadiolone, are highly toxic to rodents, and a single feeding on baits with an active ingredient concentration as low as 0.005% can produce death (Marsh 1988*a*). Certain rodents have developed resistance to some of the older anticoagulants.

Anticoagulants can be obtained in prepared baits or purchased as concentrates for mixing with fresh bait. Baits should be placed where the rodents feed, drink, or travel. For anticoagulants that require continuous exposure, bait stations, purchased from pesticide supply houses or constructed from wood or metal, are particularly useful in protecting the bait from weather and nontarget species. Old automobile tires and drainage tiles also have been used. Some baits are in packets that are gnawed open by rodents. Many anticoagulants are available in a paraffin-impregnated cereal bait for use in sewers or other damp locations.

Several anticoagulants are registered for use as a tracking powder; they are dusted into burrows and along runways where house mice or Norway rats travel. The animals lick the toxic dust from their feet and fur. Chlorophacinone (Rozol®) tracking powder is registered for bat control in dwellings in some states; however, the increased likelihood for human contact with dead or dying bats as a result of its use, with the potential for rabies exposure, should be considered (Greenhall and Frantz 1993).

Non-Anticoagulants

Rodenticides with different modes of action provide an obvious answer to anticoagulant resistance. Zinc phosphide, red squill, strychnine, and Compound 1080 (sodium monofluoroacetate) are non-anticoagulant toxicants used for many years. In recent years the use of strychnine and 1080 has been severely restricted through loss of EPA registrations. The need for safe, effective, non-anticoagulant rodenticides still exists. Several new compounds (cholecalciferol, bromethalin, and alpha-chlorohydrin) are now available (Marsh 1988*a*).

Zinc phosphide, one of the most commonly used single-dose rodenticides, is relatively safe to humans, and its use usually does not result in secondary poisoning of nontarget species. Efficacy is poor or inconsistent on some field rodents but often can be improved by prebaiting (Marsh 1988*b*). Zinc phosphide baits are prepared with sweet potatoes, carrots, or apples for nutria and muskrats; apples, cracked corn, or oats for voles and pocket gophers; oats for prairie dogs; and ground fish or meat for commensal rodents.

For muskrat and nutria control, bait can be placed on 1- × 1-m rafts constructed of marine plywood and anchored near the area of use. Prebaiting is necessary to assure success in nutria control (LeBlanc 1993).

Control methods for voles vary with the situation and species involved. Bait can be scattered along surface runways or placed in underground runways. In orchards, bait placed under boards or asphalt shingles inside the drip line of fruit trees takes advantage of the tendency for voles to burrow and nest under such objects. Tobin and Richmond (1987) described a bait station for voles made from polyvinylchloride (PVC) pipe.

A 2% zinc phosphide on steamrolled oats is used to control prairie dogs. After prebaiting with oats for 1–3 days, toxic bait is then scattered by hand around each burrow entrance (Tietjen 1976). A 2% zinc phosphide bait significantly reduced cotton rat (Holler and Decker 1989) but not roof rat populations (Lefebvre et al. 1985*b*) in Florida sugarcane fields. Strychnine- and 1080-treated grain also have been used to control various field rodents.

Red squill is an imported, relatively safe, plant-derived rodenticide that has shown only moderate effectiveness on Norway rats. A newer, more effective form has been developed and marketed in Europe (Marsh 1988*a*).

Cholecalciferol (vitamin D_3; marketed as Quintox® and Rampage®) is both a single- and multiple-feeding toxicant effective on commensal rodents (Marshall 1984). No secondary hazards have been associated with its use (Marsh 1988*a*). Bromethalin (marketed as Vengeance® and Assault®) is another new rodenticide effective on rats, including those resistant to warfarin (Marsh 1988*a*).

BURROW BUILDER

The burrow builder is a tractor-drawn mechanical tool that constructs an underground artificial burrow and places toxic grain baits therein for controlling pocket gophers (Fig. 13). During their underground travels, gophers intersect the artificial burrows, consume the toxic bait, and die underground. Artificial burrows are constructed 6–9 m apart, usually 20–30 cm deep. The proper depth to set the machine can be determined by locating and measuring the depth of gopher burrows by probing with a pointed instrument. Up to 40 ha of land can be treated in a day with this tool.

The trail builder is a variation of the burrow builder. The burrow is shallower and its diameter less than that constructed by the burrow builder. Zinc phosphide-treated grain typically is placed in the burrows to control vole damage in orchards or tree plantings (Anderson 1969).

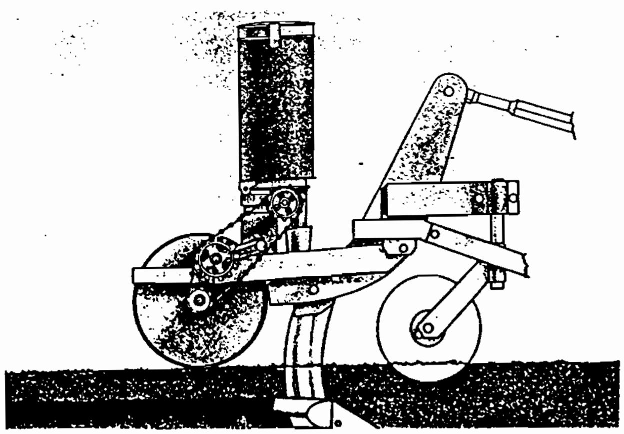

Fig. 13. **Burrow builders are tractor-drawn mechanical devices used to create an artificial underground burrow and place toxic grain baits therein for controlling pocket gophers. Gophers intersect these burrows during their normal activity, feed on the bait, and die underground (sketch courtesy of Univ. California, Davis).**

TRAPS

Live Traps

Live traps capture small mammals unharmed. They are excellent for use in residential areas or in situations where animals doing the damage may be transplanted to another location. These traps, in various shapes and sizes, can be homemade of wire or wood, or bought commercially. Some traps have doors at both ends, which allow animals to see through, therefore reducing reluctance to enter. Suggested baits include apple slices, sunflower seeds, peanut butter, and rolled oats.

The Bailey and Hancock live traps, used to capture beavers, are made of flexible mesh wire. When set, the Bailey trap resembles an open suitcase and the Hancock a half-open suitcase. When the triggering device is tripped the trap closes and the animal is caught between the two halves. These traps are best suited for use at entrance and exit routes of the lodge or in water travel lanes. The traps can be baited with an ear of corn or a fresh piece of aspen or other edible woody plant (Anderson 1969). They are used primarily to capture individual beavers for relocation; they are not efficient for intensive trapping efforts.

Leg-Hold Traps

Leg-hold traps, also called steel traps, are manufactured in several different sizes and are available with padded or unpadded jaws (Fig. 14). Their use is controversial; however, properly used they are effective and valuable. Some states prohibit their use, whereas others require that only traps with padded jaws be used. They are most extensively used for beaver, muskrat, and nutria control, but smaller sizes are used to capture tree and ground squirrels, rats, and woodchucks.

Traps can be set in travel lanes or near burrow openings without bait (blind sets), or they can be set adjacent to bait or various lures. Traps placed underwater for beavers and muskrats usually are set at burrow entrances or exit points from the water. Stakes or anchor material should be placed in the water in such a way that the trapped animals will seek deep water and drown, thus preventing them from twisting out. The Canadian Trappers Federation (no date) provides descriptions of various sets used for beavers and muskrats. Prairie dogs, ground squirrels, and mountain beavers can be caught by burying the traps near the burrows, using a pan cover, and covering the traps with soil. Scattered grain then is placed on the traps. Prebaiting may improve trapping success.

Body-Gripping Traps

Conibear traps are body-gripping traps chiefly used in water sets for muskrats, nutria, and beavers (Fig. 14). Manufactured in three sizes, they have the humane feature of killing quickly. This may also be a disadvantage, because any nontarget animal caught is killed as well. These traps have a pair of rectangular wires that close like scissors when released, killing the animal with a quick body blow. Conibear traps are lightweight and easy to use. They can be placed at the entrances of burrows and lodges and in dams, runs, and slides. The Canadian Trappers Federation (no date) also provides descriptions of sets for these traps. Care should be taken when large conibear traps are used because of the hazard to pets and children. A safety device is available that should be used when the large size is set. Some states prohibit their use in dry-land sets.

Somewhat similar body-gripping traps are available for moles and pocket gophers. For moles, the trap is placed in a section of the runway that has been pressed down. The trap is activated when the mole traveling the runway raises the depression, trips the trap, and is caught by the loops or scissors-like devices. The harpoon trap is used in a similar fashion, but instead of the mole being caught, it is speared by a spring-loaded harpoon.

Snap Traps

Advantages to using snap traps to control rats and mice include less danger to children or pets than with some chemicals, easy recovery of killed animals, and no contaminants. A snap trap's efficiency often can be increased by enlarging the bait pan with a heavy piece of cardboard or stiff screen wire. Obstacles such as boxes or boards can be used to funnel rodents to traps. Baits include peanut butter with uncooked oatmeal, a small piece of bacon or apple, or a raisin. These traps can be used outdoors to capture small field rodents when only a few animals are involved or to capture animals for identification or population indexing purposes.

SNARES

Beavers can be captured as effectively with snares as with conibear or leghold traps (Weaver et al. 1985). Snares cost and weigh less than traps and permit release of nontarget captives. Weaver et al. (1985) provided detailed instructions for their use. Snares are also effective in controlling small populations of rabbits. The animals must be traveling a well-defined trail or through a specific entrance such as a hole in a fence. Snares are made of a light wire or cable looped through a locking device, or a small nylon cord tied so it will tighten as the animals push against it. State game regulations should be checked before snares are used.

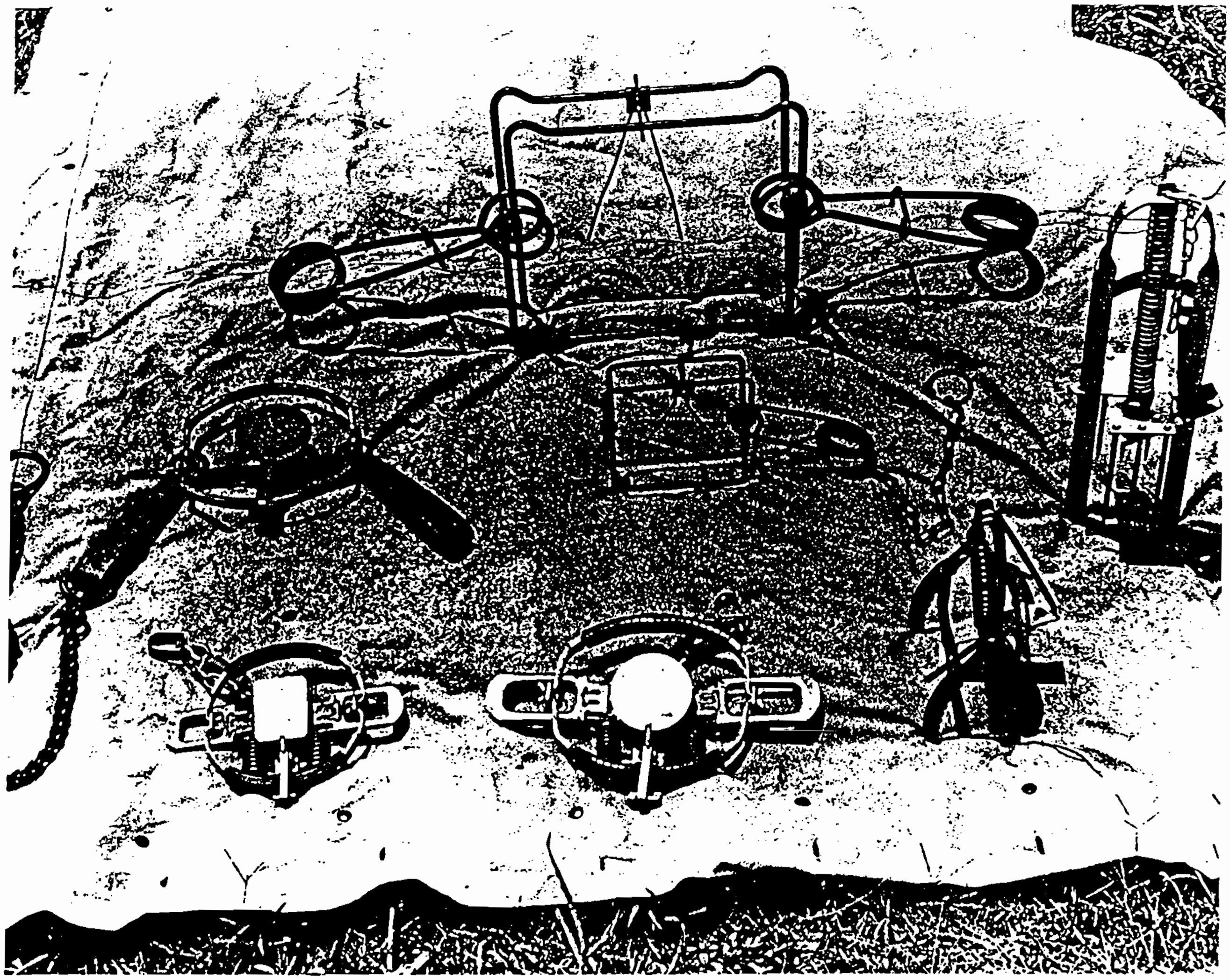

Fig. 14. A variety of traps is used in the control of rodents and other small mammals. Shown here are: top—#330 conibear; middle row (left to right)—double-long spring leg-hold, #110 conibear, harpoon mole trap; bottom row (left to right)—#1½ Victor soft catch leg-hold, #3 Woodstream soft catch leg-hold, scissors mole trap (photo, F. Boyd, USDA/APHIS).

CHEMICAL REPELLENTS

Several compounds have been registered for use as small-mammal repellents (Jacobs 1993); however, definitive efficacy data for most of these are lacking. The use of some area repellents, such as naphthalene or para-dichlorobenzene, in structures often is limited because the vapors cannot be prevented from permeating areas occupied by people. Efficacy of repellents placed on plants or seeds is affected by availability of natural foods and ability to withstand weathering. Thiram, the most widely used taste repellent, can be applied to trees, tree seeds, seedlings, bulbs, and shrubs to protect them from various rodent species and moles. This compound cannot be used on plant parts eaten by humans or domestic animals. Fruit trees must be sprayed only in the dormant season. Thiram and methiocarb, when used as seed treatment, protected newly planted corn from rodent damage (Johnson et al. 1985, Holm et al. 1988).

SHOOTING

Shooting can be a selective method of eliminating individual pest mammals. Small-bore shotguns, rifles, and air guns can be used. Some animals such as beavers, muskrats, and nutria can be shot most effectively at night by using a spotlight with a red lens. Shooting is especially useful in controlling animals with low reproductive rates, such as porcupines. Local game codes should always be reviewed before shooting is used. Shooting at night, and in particular with a spotlight, is not legal in some states.

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. E. W. Pearson (unpubl. final rep., U.S. Fish Wildl. Serv., Denver Wildl. Res. Cent., 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 annual losses of sheep and lambs to coyotes and other predators ranged from $69 million to $83 million in 1985–87. 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, one-half of what was needed to sustain the population (Cowardin et al. 1985). The red fox apparently is the most serious waterfowl predator because it is adept at catching nesting hens as well as destroying eggs (Sargeant et al. 1984).

Predation is rarely observed; therefore, 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 often will indicate the species causing predation. Extensive bleeding usually is characteristic of predation. If external bleeding is not apparent, the hide can be removed from the carcass, particularly around the neck, throat, and head, and the area then is 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 fresh (Wade and Bowns 1982).

Animals may not always be killed by being bitten at the throat, but may be pulled down from the side or rear, often with blood on the sides, hind legs, and tail areas. Tails of calves may be 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 the species causing the problem.

Species Damage Identification

BADGERS

Badgers eat primarily rodents such as mice, prairie dogs, pocket gophers, and ground squirrels. They also will prey on rabbits, especially 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. Their dens in crop fields may slow harvesting or cause damage to machinery, and their digging can damage earthen dams or dikes (Lindzey 1993).

Badgers usually eat all of a prairie dog except the head and the fur along the back. This characteristic probably holds true for most 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, and impressions from the long toenails are apparent in most situations.

Control Techniques.—Frightening devices, leg-hold traps (#3–4), shooting, snares.

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 often are 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 remain. Feces generally are found within the kill area, and a bedding site often is 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, the carcass 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) observed that most cattle are killed by a bite through the back of the neck. A large prey often has 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 sometimes are 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 also may play havoc with garbage cans, cabins, campsites, 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 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).

Control Techniques.—Hunting dogs, live trapping, foot snares, fencing, shooting, leg-hold traps (#5, 6, and 15) where legal.

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. Characteristically, bobcats 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 the bobcat was holding the lamb with its claws while biting the neck. Small fawns, lambs, and other small prey often are killed by a bite through the top of the neck or head (Young 1958). The hindquarters of deer or sheep usually are preferred by bobcats, although the shoulder and neck region or the flank sometimes are eaten first. The rumen is often untouched. Poultry usually are killed by biting the head and neck (Young 1958); the heads usually are eaten. 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 30–35 cm in scratching litter, compared to a 90-cm reach of a mountain lion (Young 1958). The distance between the canine teeth marks also will help distinguish a lion kill from that of a bobcat—3.8 cm vs. 1.9–2.5 cm, respectively (Wade and Bowns 1982).

Control Techniques.—Hunting dogs, snares, calling and shooting, leg-hold traps (#3–4), aircraft (under some specific circumstances), frightening.

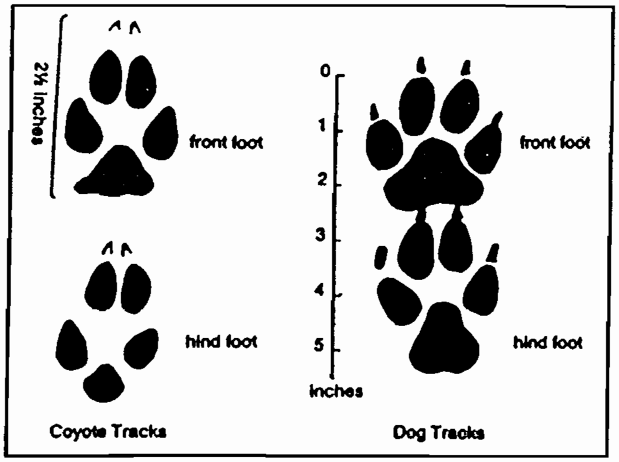

Fig. 15. Coyote and dog tracks are similar. Coyote tracks are more rectangular with the toes closer together, whereas dog tracks are more round with the toes spread apart (from Dorsett 1987).

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 can penetrate the top of the neck or the skull. Calf predation by coyotes is most common when calves are young. Calves attacked, but not killed, exhibit wounds in the flank, hindquarter, or front shoulder; often their tails are chewed off near the top. Deer carcasses frequently are completely dismembered and eaten (Bowns 1976).

Complaints of pets being killed by coyotes have increased with urbanization (Howell 1982). Avocado producers using drip irrigation systems report that coyotes chew holes in plastic pipe and disrupt irrigation (Cummings 1973). Watermelons are damaged by coyotes biting a hole through the melons and eating out the center. This differs from raccoon damage to melons; raccoons make small holes in the melons and scoop out the pulp with their front paws. Coyotes also will 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 and rarely kill as effectively as coyotes (Green and Gipson 1993). Normally little flesh is consumed. They 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 usually are 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 on the two middle toes (Fig. 15). Coyote tracks appear in a straight line, whereas those of a dog are staggered.

Control Techniques.—Fencing, herding, den hunting, calling and shooting, shooting from aircraft, guarding dogs, snares, M-44s, frightening, livestock protection collar, leg-hold traps (#3–4½).

FOXES

Gray and red foxes feed primarily on rabbits, hares, small rodents, poultry, birds, and insects. They also will consume fruits. The gray fox also eats fish, 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 prey 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 usually are opened enough to allow the contents to be licked out. The shells are left beside the nest and rarely are 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 usually are 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 often are partially buried.

Foxes, like other wild canids, return to established denning areas year after year. They dig dens in wooded areas or open plains. Hollow logs also are used. Dens may be identified by the small, dog-like 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.

Control Techniques.—Dogs (hunting and guarding), leg-hold traps (#2–3) denning, calling and shooting, fencing, shooting from aircraft, M-44s, snares, frightening.

HOGS

Problems associated with feral or wild hogs have increased across the southern U.S. Rooting and wallowing by wild hogs can damage agricultural crops and timber and also damage farm ponds and irrigation dikes (Barrett 1993). Wild hogs also feed on young sheep and goats in certain parts of the U.S. 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 90-kg calf. In soft ground dewclaws will show on adult hog tracks (Barrett 1993).

Control Techniques.—Live traps, snares, hunting dogs, shooting from aircraft.

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 1 night. However, five to ten 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 upon the front quarters and neck region of their prey. The stomach generally is untouched. The large leg bones may be crushed and ribs may be broken. Many times, after a lion has made a kill, the victim is dragged or carried into bushy areas and covered with litter. A lion might return to feed on a kill for 3 or 4 nights. They normally uncover the kill at each feeding and move it 10–25 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 10 cm in length and 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.

Control Techniques.—Dogs (guarding and hunting), snares, leg-hold traps (#4½ and 114).

OPOSSUMS

Opossums are omnivorous, eating fish, crustaceans, insects, mushrooms, fruits, vegetables, eggs, and carrion. They will 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 are 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 remain.

Control Techniques.—Live traps, leg-hold traps (#1–1½), shooting, dogs, exclusion fencing.

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 experience severe damage from raccoons. Ripening corn frequently is eaten and much is wasted (Conover 1987*b*) (Fig. 2). Raccoons raid nesting cavities of birds (Lacki et al. 1987). They occasionally kill small lambs, usually by chewing the nose.

Occasionally, raccoons enter poultry houses and take many birds in 1 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) reported that eggshells were located within 9 m of the nest.

The raccoon leaves a distinctive 5-toed track resembling a small human hand print. Tracks usually are paired, and the left hind foot is placed beside the right forefoot (Murie 1954). Raccoon and opossum tracks can be difficult to distinguish in soft sand where toes do not show.

Control Techniques.—Hunting dogs, live traps, leg-hold traps (#2–3), exclusion fencing, shooting.

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 usually are 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 1 m away.

Most rabbit, chicken, and pheasant carcasses found at skunk dens are carrion that has been dragged to the den site (Crabb 1948). When skunks do 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 near the mound or hole containing undigested insect parts. Hair and rub marks also may be present. Dens usually have a characteristic skunk odor, although it might not be strong.

Control Techniques.—Live traps, leg-hold traps (#1–1½), fumigants, shooting.

WEASELS AND MINK

Weasels and mink have similar feeding behaviors, killing prey by biting through the skull, upper neck, or jugular vein (Cahalane 1947). 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, ribs, and pieces of the adjacent hide, the 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 15–20 mm in diameter. Close inspection of shell remains frequently will disclose finely chewed edges and tiny tooth marks (Rearden 1951).

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

Control Techniques.—Leg-hold traps (#1–1½), conibear traps, fencing, barriers.

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 often are strewn over several square meters in open areas. The meaty portions of large birds are consumed entirely, and loose skin with feathers attached is left. Small birds generally are consumed and only the wings and scattered feathers remain. Cats usually leave tooth marks on every exposed bone of their prey. Nesting birds particularly are 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 often are extremely wary.

Control Techniques.—Live traps, shooting, leg-hold traps (#1–1½).

Control Techniques

SHOOTING FROM AIRCRAFT

Various kinds of fixed-wing aircraft have been used to control wolves, coyotes, bobcats, and foxes, but the Piper Super Cub, with a 150-horsepower engine, is preferred. The pilot and gunner sit in tandem in this two-seat aircraft; this allows both occupants to see out both sides of the aircraft. Hunting is more effective on snow because target animals can be seen and tracked more easily. When the hunted animal is found, the pilot makes an approach over it at approximately 20 m of altitude, preferably into the wind. The ground speed of the aircraft is around 60–85 km/h at this point, but the airspeed should never be near the stalling speed of the aircraft. A 12-gauge semiautomatic shotgun is the most common weapon used, and number 4 buck-shot, BB, and number 2 shot are preferred.

Several modifications have been made to the Super Cub to increase safety and effectiveness. These modifications include a larger propeller called the Alaskan Super Prop and drooped wingtips to provide added power, stability, and maneuverability, particularly at higher altitudes. Larger balloon-type tires have been added to provide clearance for the longer propeller and to better utilize primitive runways for landings. The 160-horsepower engine is becoming more popular due to its added power and greater fuel efficiency (Vetterman 1985).

Rotary-wing aircraft (helicopters) have been used in recent years for predator control. The helicopter, with its ability to hover, can be used more effectively than fixed-wing aircraft in rougher and brushy terrain. In models with a plexiglass bubble cockpit, the visibility and consequent tracking ability are good.

The fixed-wing craft and helicopter sometimes are operated together. The helicopter is used for dispatching the animal, while the fixed-wing flies above the helicopter and maintains surveillance. This combination works well in areas with thick vegetation or where animals have been hunted heavily with the helicopter. These "chopper-wise" animals try to evade the hunters but can be spotted with the fixed-wing craft. Radio contact between the two aircraft is necessary.

Aerial hunting can be more efficient if one or more ground crews work with the aircraft. The ground crew induces coyotes to howl by using a horn, siren, voice, or recorded howl. When animals respond, the aircraft is directed into the area by two-way radio communication. Early morning and late afternoon are the most productive times for aerial hunting.

Federal law requires each state where aerial hunting is allowed to issue aerial hunting permits. Some states also require low-level flying waivers.

CALLING AND SHOOTING

Calling and shooting is a selective means to control coyotes, bobcats, and foxes. It has become a popular sport, and for some people it is not calling and shooting, but calling and photographing.

Several commercial calls are available, as are recorded calls. Open-reed predator or duck calls work well but require more practice. The call is blown to imitate the sound of a rabbit in distress. This sound either arouses the predator's curiosity or indicates an easy meal. Of course, some predators become wise to the call. Conversely, the call may be an effective method to attract a trap-wise animal.

Three factors must be kept in mind when calling is used: (1) ensure that the area being called to is upwind to prevent the predator from detecting the caller's scent before the animal comes into shooting range; (2) have a full view of the area being called so that the predator will be unable to approach unseen; and (3) avoid being seen by wearing camouflage clothing and hiding in vegetation.

The most effective times to call are early morning and late afternoon. The hunter can gain an added advantage by locating coyotes before beginning the call by inducing howls as previously described under aerial hunting. Calling at night and using a spotlight can be effective; however, local game laws should be checked.

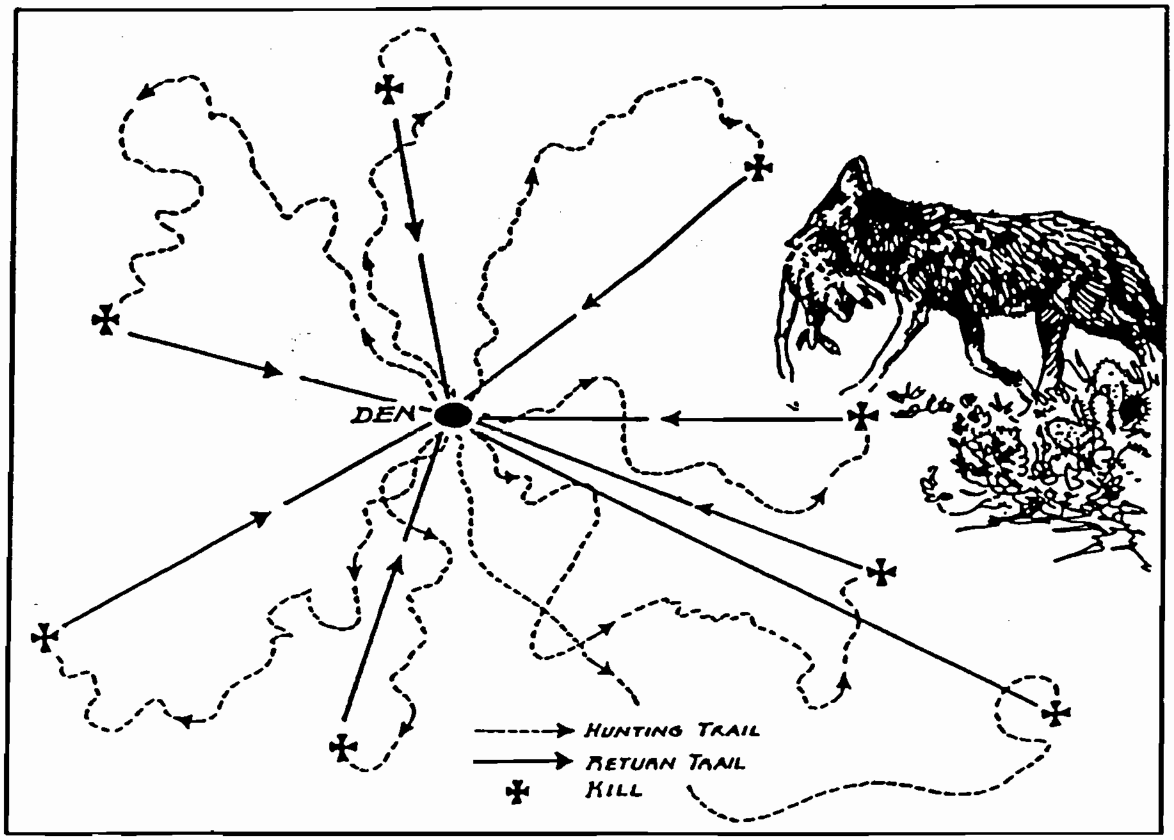

Fig. 16. The tracks of a coyote that is hunting away from the den site will be meandering. When the coyote is returning to the den site, it will travel the straightest possible route (from Presnall 1950).

DENNING

In the spring, depredation on livestock and poultry by coyotes and foxes might indicate a nearby den that has increased the food requirement for support of the pups as well as the adults. Till and Knowlton (1983) reported that sheep losses to coyotes were greatly curtailed after removal of adults and pups or only pups of coyotes responsible for the losses. Removal of the entire litter usually will end the losses of livestock; however, this is dependent on the availability of other food sources and preferences.

Dens are located by tracking or observing the adults. Den hunting is based on the principle that adults tend to follow irregular routes while searching for prey, but once food is secured they return to the den in the most direct route possible (Fig. 16). The experienced observer can distinguish between these tracks.

An active den is evident by hairs around the entrance, fresh tracks, and, if the pups are large enough to come out of the den, matted and worn vegetation around the entrance. Fox dens usually have remains of prey brought in for food. This observation is not common at coyote dens.

Den hunting is difficult, time-consuming work, particularly on hard ground, in heavy cover, and during high winds. A good dog is a great help in locating dens. Some dogs are trained to return to the hunter when the adult predator tries to chase them out of the den area. This behavior usually will get the target animal within rifle range. A call blown to imitate a frightened or injured pup sometimes will bring adult coyotes within rifle range. Care should be taken while digging out dens because of the possibility of cave-ins and ectoparasites. These hazards are eliminated if a gas cartridge is used in coyote dens.

Use of aircraft is a good method for locating coyote and fox dens. This is done during normal aerial hunting operations by looking for animal signs as well as the animals. Den signs include cleaned-out holes and worn vegetation (Vetterman 1985).

FRIGHTENING DEVICES

Devices such as lights, loud music or noise, scarecrows, plastic streamers, aluminum pie pans, and lanterns have been tried to frighten away predators. All of these devices can provide a temporary benefit in reducing damage or deterring predators. Changing the location or combination of techniques being used can prolong the frightening effect, but the effectiveness decreases when the predators become accustomed to the noise, lights, or objects.

Linhart (1984) reported that the use of warbling-type sirens and strobe lights in combination reduced lamb losses from coyotes by 44%. These battery-operated devices were activated in the evening by a photocell set on a schedule of 10-second bursts at 7- to 13-minute intervals. In a survey of North Dakota ranchers, Pfeifer and Goos (1982) reported the use of propane exploders delayed or prevented lamb losses to coyotes for a period of time to allow other control methods to be employed. The most important factors contributing to success were properly operating and maintaining the device, moving the device to different locations, and changing the firing intervals.

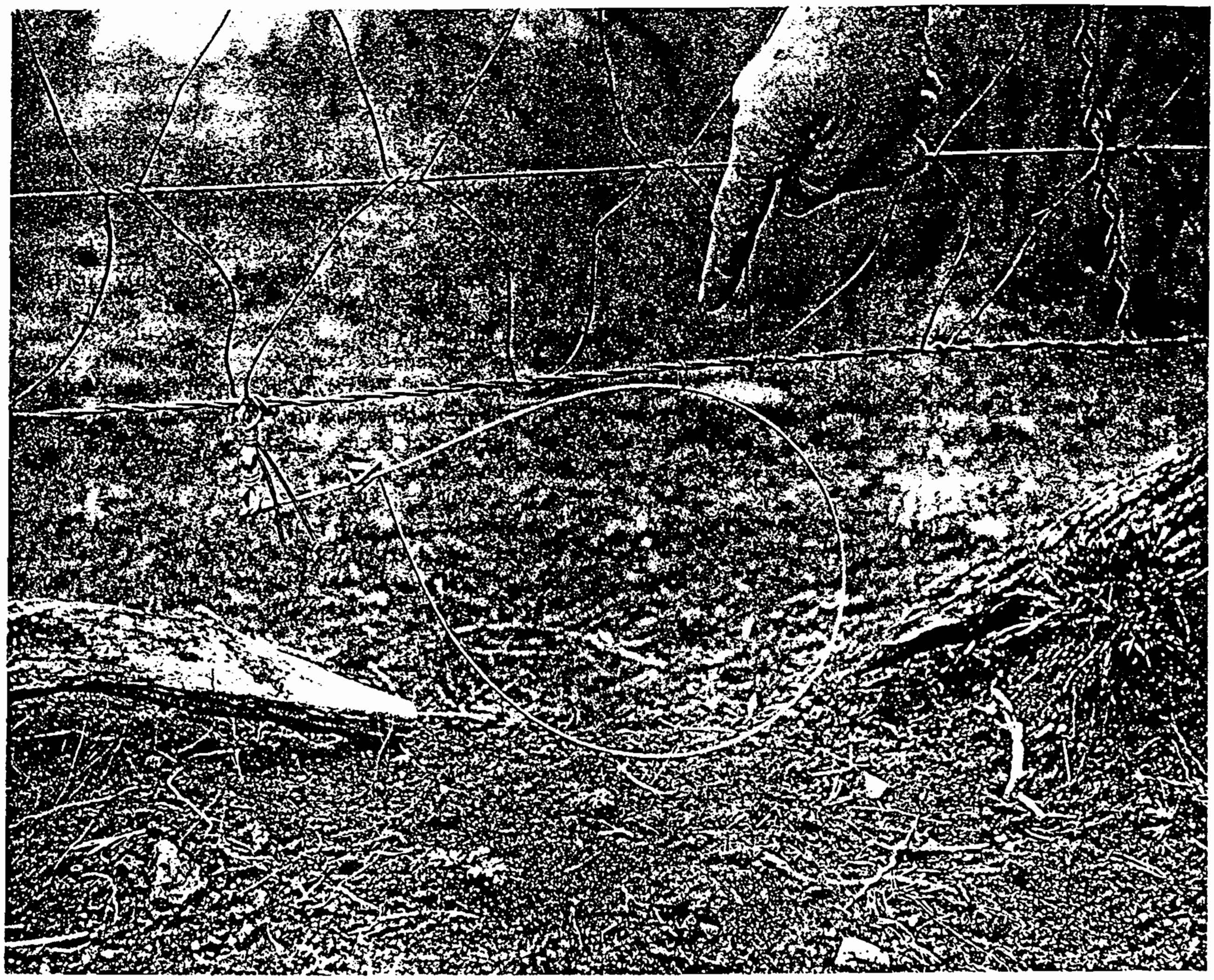

Fig. 17. The body snare, used primarily to capture coyotes, should be positioned directly under the fence with the top of the loop attached by a small, thin wire or a single strand of sewing thread. The attachment should release with the slightest pull (from Sims 1988).

HUNTING DOGS

Two types of dogs are used in predator control work. Dogs that hunt by sight, such as greyhounds, are kept in a box or cage until the predator is seen, then released to catch and kill the animal. This type of dog is effective only in relatively open terrain. The other type of dog is the trail hound, which follows an animal by its scent. Trail hounds hunt on bare ground; however, snow or heavy dew makes trailing easier. Hot, dry weather makes trailing difficult; therefore, early morning with dew is the most effective time. Several breeds such as bluetick, black and tan, Walker, and redbone, usually run in packs of two to five, are used.

Trained trail hounds are used to catch and "tree" raccoons, opossums, bobcats, bears, and mountain lions. Often these dogs are able to track the offending animal from a kill, thus making this control method highly selective. Local game codes should be checked before this type of control is used.

GUARDING DOGS

For centuries dogs have been used to work livestock, but only in the past 15 years has interest in guarding dogs caught the attention of the livestock industry. The three more common breeds used are the Great Pyrenees, komondor, and Akbash. All have been used effectively in fenced pasture situations, but Pyrenees have shown the most success on open-range flocks (Green et al. 1984). Mixed-breed dogs also have been used (Black and Green 1984). Guarding dogs must possess three behavioral traits: trustworthiness with sheep, attentiveness to the sheep, and aggressiveness to attack and chase potential predators (McGrew and Andelt 1986). The guarding dog puppy develops a bond with sheep by being placed with them at 6–8 weeks of age. For range operations, the ideal time to place a dog with the sheep is when the sheep are confined in a pasture or fenced area or after lambing when the main flock is being formed (Green and Woodruff 1983).

A critical factor in the success of guarding dogs is the handler's ability to train and use these animals, which requires patience and understanding. According to Green and Woodruff (1983), the most serious problem encountered by some producers is a disillusionment that the use of guarding dogs will be an immediate solution to their predator problem.

LIVESTOCK PROTECTION COLLAR

The livestock protection collar, also called the toxic collar, consists of several rubber pouches containing Compound 1080 attached with straps around the throat of a sheep or goat. Collars are designed to kill coyotes that puncture the pouches while attacking the throats of targeted livestock. The collar offers certain advantages over other methods of coyote control by specifically removing only those animals responsible for predation. It is particularly effective for coyotes that have become wary and avoid other control methods (Connolly and Burns 1990). The primary disadvantages of collars are the cost and labor of their application; the compartments being punctured by thorns, wire, or snags; and the EPA-required monitoring of the flock with collared animals (Wade 1985).

SNARES

Snares are made of varying lengths and sizes of wire or cable looped through a locking device that allows the snare to tighten. The two types of snares are body and foot. The body snare is used primarily on coyotes. This snare is set where the animals crawl under a fence, at a den entrance, or in some other narrow passageway. The device is looped so that the animal must put its head through the snare as it passes through the restricted area (Fig. 17). When the snare is felt around the neck, the animal normally will thrust forward and tighten the noose.

The foot snare is spring-activated. When the animal steps on the trigger the spring is released, lifting the noose and tightening it around the foot. This device has been used effectively to capture mountain lions and grizzly and black bears. The foot snare can be used in a bear pen or cubby set. This pen is just large enough to accommodate the bait, which usually is the carcass remains of an animal killed earlier by the predator. The pen can be built of brush or poles and has an open end where the snare is set. The pen and guide sticks will force the bear to step into the snare while trying to reach the bait. Bacus (1968) described a pipe snare set that consists of a 0.9-kg coffee can (or a similar length of 13-cm pipe) with a 2.5-cm slot cut down the side to accommodate the trigger. The can is buried, and the loop is laid loosely on the ground around the outside of it and covered with dirt. Bacon grease is melted into the can with a torch. A rock is placed on top of the can to prevent nontarget animals from tripping the snare. A bear can roll the rock off but, being unable to reach the bait in the bottom of the can with its mouth, will reach in with its front foot and spring the snare. Bears also can be caught with the foot snare in a trail set.

The foot snare also can be used to capture mountain lions. It should be set in a narrow trail known to be traveled by the target animal. Deer and livestock can be prevented from interfering with the snare with a pole or branch placed across the trail, directly over the set and about 0.9 m above the ground.

The selectivity of the foot snare may be improved by placing sticks under the trigger that break only under the weight of heavier animals. Foot snares have advantages over large bear traps in that they are lighter, easier to carry, and less dangerous to humans and nontarget animals.

TRAPS

Live Traps

Live traps, as discussed in RODENTS AND OTHER SMALL MAMMALS (p. 483), are available in various sizes to capture small predators as well as larger ones such as bears. Coyotes, foxes, and bobcats are difficult to live-trap because of their caution and reluctance to enter the confined area of the trap.

Canned dog or cat foods are effective baits to entice raccoons, opossums, skunks, and cats into live traps. Traps for skunks should be covered with a canvas or heavy cloth and provided a flap for the door. When a skunk is captured, the trapper can walk up to the trap on the covered side and drop the flap over the door. The skunk then can be transported to the release site. To release, the trapper should stand beside the trap and ease the flap and door open; the animal will flee and usually not look back.

Problem bears can be caught in a live trap made from steel culverts equipped with a trapdoor and trigger device. They normally are mounted on trailers to permit bears to be easily moved to other locations for release.

Leg-Hold Traps

Leg-hold or steel traps are manufactured in various sizes. The following trap sizes are recommended for the animals listed:

- #0 and 1 for weasels and ground squirrels
- #1 and 1½ for skunks, opossums, mink, feral cats, and muskrats
- #2 and 3 for foxes, raccoons, small feral dogs, nutria, marmots, and mountain beavers
- #3 and 4 for bobcats, coyotes, large feral dogs, badgers, and beavers
- #4 and 4½ for wolves
- #4½ and 114 for mountain lions

Success in trapping depends greatly on placing the trap where the predator regularly travels. A trap usually is set in the ground by digging a shallow trench the size of the trap (Fig. 18) and deep enough to allow the stake (or drag) and chain to be placed in the bottom of the trench and covered with soil. The trap is set firmly on top of this and should be about 11 mm below the soil surface. A canvas or cloth is placed over the pan and under the jaw to prevent soil from getting beneath the pan and preventing its release. The trap then is covered with soil and other material natural to the area surrounding the trap. The trap can be set unbaited in a trail being traveled by the target animal; this is called a "blind" or trail set. Traps also may be set off the trail and used with a lure. The lure set is more selective and is made more so by the type of lure used.

The dirt-hole set is effective for raccoons, foxes, and mink. The trap is set in the same manner as the baited set, but instead of placing the scent on the vegetation or ground, the lure is placed in a small hole, about 15 cm deep, dug on a slant behind the trap.

The bear trap is extremely large, powerful, and dangerous to humans, livestock, and pets. The bear foot snare is as effective and much safer to use, so bear traps are not recommended and are no longer legal in some states.

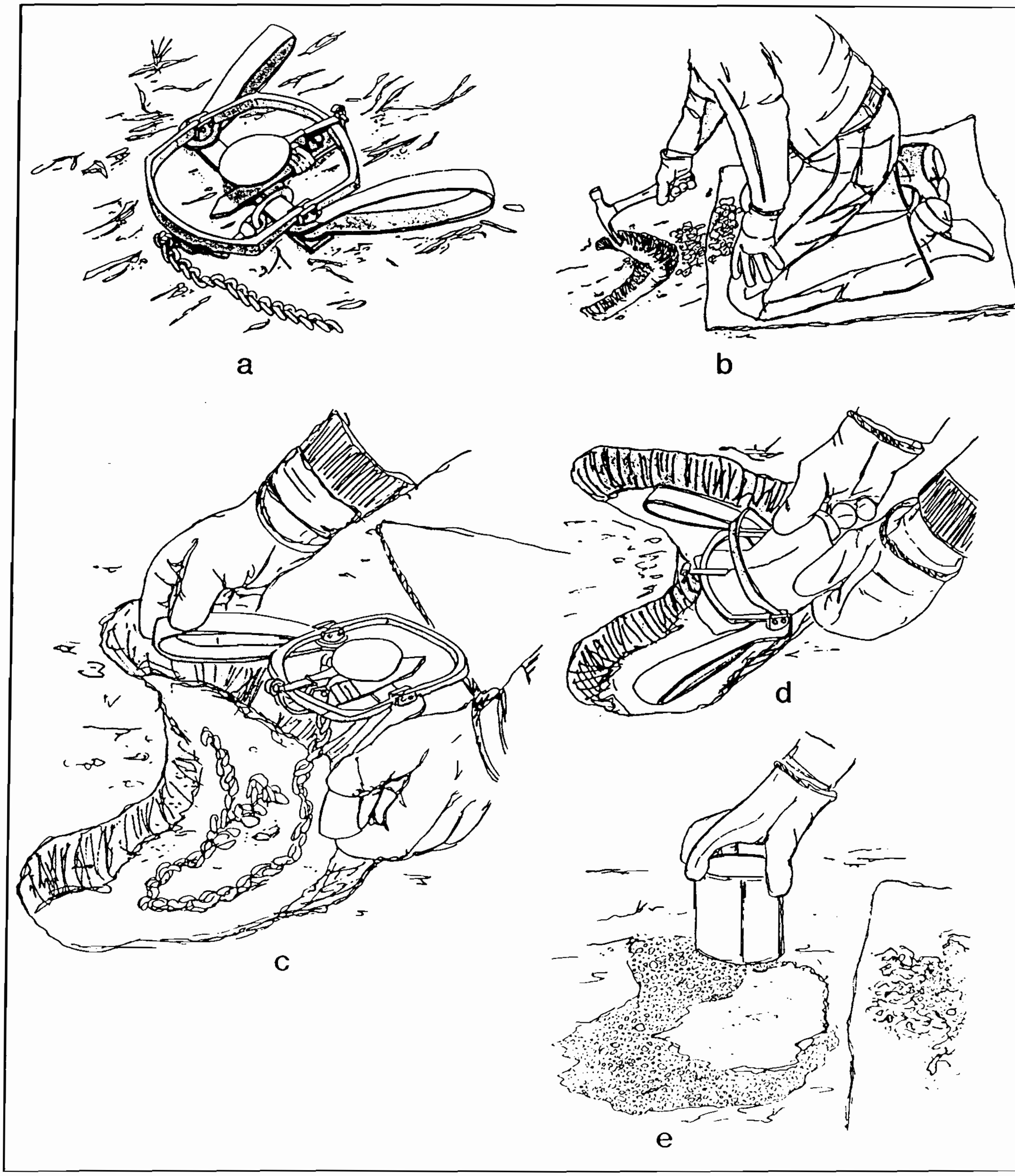

Fig. 18. a. A leg-hold trap is first laid on the ground to determine best location of hole. b. The hole should be about 11 cm deep and shaped to accommodate the trap. c. If a stake is used, it is driven into the bottom of the hole. If a drag is used, it is placed in the hole. The chain is then put into the hole and covered with soil until the hole is about 3 cm deep and packed to provide a firm foundation. d. The front jaw is raised and the pan cover is placed over the pan so soil cannot get under the pan. e. The trap is covered with finely sifted soil to a depth of 0.6–1.2 cm. A stick or whisk broom is used to touch up and make set appear as natural as possible (from Dorsett 1987).

The location of a trap set influences its selectivity. When placed beside a carcass, a trap can catch nontarget animals such as vultures, eagles, badgers, and other carrion-feeders. Nine meters away from the carcass normally is a safe distance to set traps to avoid nontarget animals. Weather also can affect the operation of traps. Frozen or wet ground can prevent a trap from springing.

Leg-hold traps must be checked often to prevent the lengthy restraint of captured animals. Most states have laws on the types of traps, baits and sets, and trap visitation schedule.

FENCING AND BARRIERS

Livestock, poultry, and crops can be protected from predation with properly placed fencing and barriers. Ordinary fencing will not keep most predators from gardens or poultry ranges. However, many of them can be excluded by adding a single wire strand electrified by a commercial fence charger, 20 cm out from the fence and 20 cm above the ground. Storer et al. (1938) reported success in keeping bears out of storehouses and other areas by the use of a specifically designed electric fence. An antipredator electric fence can provide some producers with a self-help method of effectively preventing coyote depredation of livestock (Nass and Theade 1988). One design is a fence 1.5 m high with 12 alternating ground and charged wires spaced 10–15 cm apart (Gates et al. 1978).

Skunks can be controlled around a poultry range by surrounding the range with a 0.9-m wire-netting fence set 0.6 m above ground and 0.3 m below the surface; a 15-cm length of the part below the surface is bent outwardly at right angles and buried 15 cm deep. Mink and weasels can be excluded from domestic animal quarters by covering all openings larger than 2.5 cm with metal or hardware cloth.

All holes in foundations of buildings should be closed or screened to prevent small predators such as skunks and opossums from living in or under them. If they have already established a home, all entrances except one should be closed. The soil should be loosened or flour should be sprinkled in front of the hole so a track can be detected. The area should be checked for tracks after dark, and if tracks indicate the animal has left the location, the opening should be sealed securely.

M-44

The M-44, registered by the EPA for the control of coyotes, foxes, and feral dogs, is a mechanical device that ejects sodium cyanide into the animal's mouth (Connolly 1988). The unit consists of a case holder wrapped with cloth, fur, wool, or steel wool; a plastic capsule or case that holds the cyanide; and a 7-cm ejector unit. The M-44 case is loaded with 12 grains (0.78 g) of sodium cyanide and an additive to reduce caking. A spring-loaded plunger ejects the cyanide. These components, when assembled, are encased in a tube driven into the ground. The cocked ejector with the case in the holder is screwed on top, placed into the tube, and baited. The bait usually is made from fetid meat, musks, and beaver castors. When an animal is attracted to the bait and tries to pick up the baited case holder with its teeth, the cyanide is ejected into its mouth. Dogs, skunks, raccoons, bears, and opossums sometimes are attracted to the bait used on M-44s; however, selectivity is enhanced by proper site and bait (scent) selections. The EPA and individual states have placed numerous restrictions on the use of M-44s.

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