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Bats (*Myotis lucifugus*)

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BATS

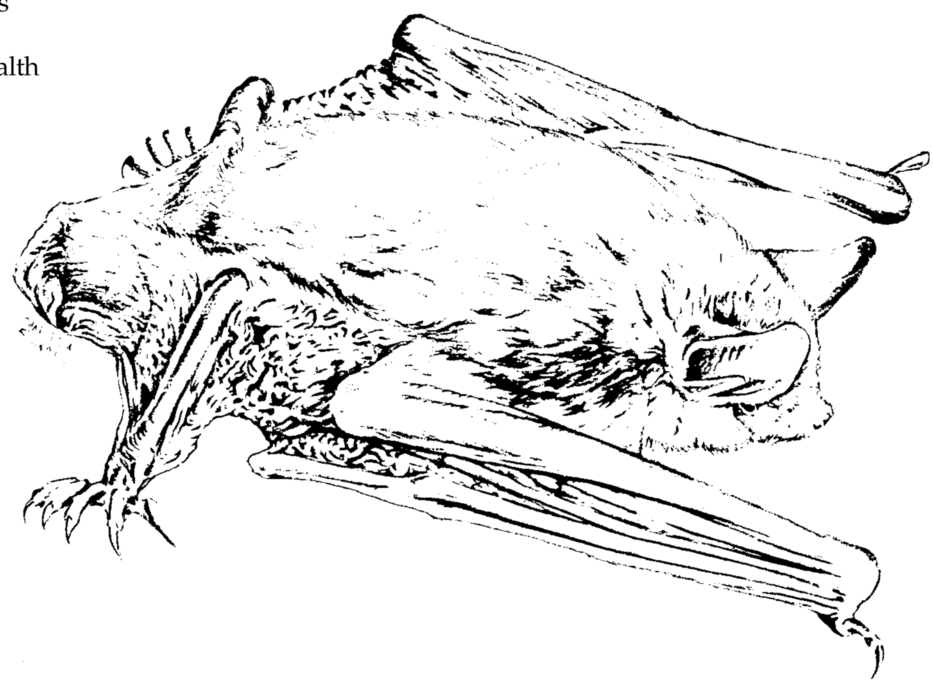

Fig. 1. Little brown bat, *Myotis lucifugus*

Damage Prevention and Control Methods

Exclusion

Polypropylene netting checkvalves simplify getting bats out.

Quality bat-proofing permanently excludes bats.

Initiate control before young are born or after they are able to fly.

Repellents

Naphthalene: limited efficacy.

Illumination.

Air drafts/ventilation.

Ultrasonic devices: not effective.

Sticky deterrents: limited efficacy.

Toxicants

None are registered.

Trapping

Available, but unnecessarily complicated compared to exclusion and bat-proofing.

Other Methods

Sanitation and cleanup.

Artificial roosts.

Removal of Occasional Bat Intruders

When no bite or contact has occurred, help the bat escape (otherwise submit it for rabies testing).

Conservation and Public Education

Information itself functions as a management technique.

PREVENTION AND CONTROL OF WILDLIFE DAMAGE — 1994

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

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

Great Plains Agricultural Council
Wildlife Committee

Introduction

Conservation and Public Education

Despite their ecological value, bats are relentlessly and unjustifiably persecuted. Bats are often killed because they live near people who needlessly fear them. These actions emphasize the need to educate the public on the reasons for bat conservation and why it is important to use safe, nondestructive methods to alleviate conflicts between people and bats. General sources of information on bats include states' Cooperative Extension Services, universities, government environmental conservation and health departments, and Bat Conservation International (Austin, Texas). Except where control is necessary, bats should be appreciated from a distance — and not disturbed.

Identification and Range

Bats, the only mammals that truly fly, belong to the order Chiroptera. Their ability to fly, their secretiveness, and their nocturnal habits have contributed to bat folklore, superstition, and fear. They are worldwide in distribution and include about 900 species, second in number only to Rodentia (the rodents) among the mammals.

Among the 40 species of bats found north of Mexico, only a few cause problems for humans (note that vampire bats are not found in the United States and Canada). Bats congregating in groups are called colonial bats; those that live a lone existence are known as solitary bats.

The colonial species most often encountered in and around human buildings in the United States are the little brown bat, (*Myotis lucifugus*, Fig. 2), the big brown bat (*Eptesicus fuscus*, Fig. 3), the Mexican free-tailed bat (*Tadarida brasiliensis*, Fig. 4), the pallid bat (*Antrozous pallidus*), the Yuma myotis (*Myotis yumanensis*), and the evening bat (*Nycticeius humeralis*).

Solitary bats typically roost in tree foliage or under bark, but occasionally are found associated with buildings, some only as transients during migration.

Fig. 2. Little brown bat, *Myotis lucifugus*

Fig. 3. Big brown bat, *Eptesicus fuscus*

Fig. 4. Mexican free-tailed bat, *Tadarida brasiliensis*

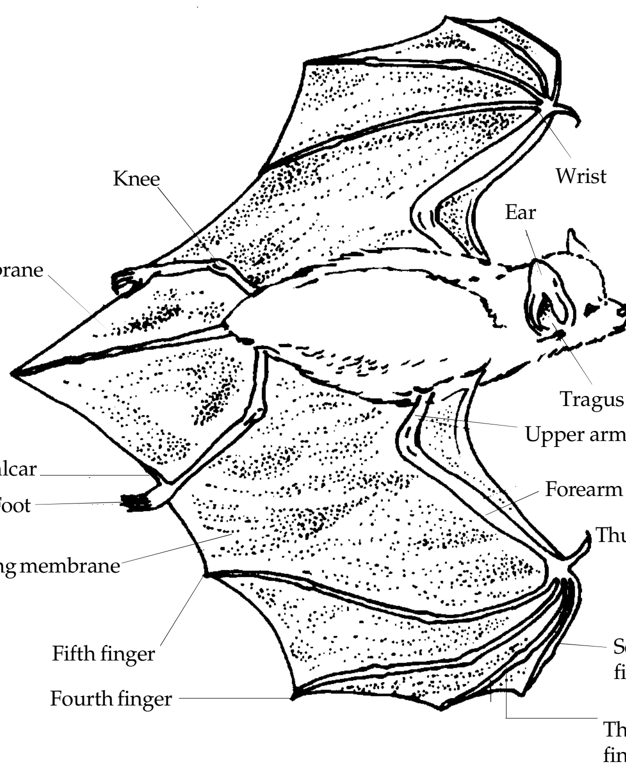

Fig. 5. Anatomy of a typical bat

These include Keen's bat (*Myotis keenii*), the red bat (*Lasiurus borealis*), the silver-haired bat (*Lasionycteris noctivagans*), and the hoary bat (*Lasiurus cinereus*). Excellent illustrations of all bats discussed herein can be found in Barbour and Davis (1979), Tuttle (1988), Geluso et al. (1987), and Harvey (1986).

Several species of bats have been included here, with significant interspecific differences that need to be clarified if well-planned, comprehensive management strategies are to be developed. Any problems caused by bats are limited to species distribution; thus animal damage control personnel need not be concerned with every species.

Colonial and solitary bats have obvious differences that serve to separate the species into groups (refer to Fig. 5). Much of the descriptive material that follows is adapted from Barbour and Davis (1979).

Colonial Bats

Little brown bat *(Myotis lucifugus)*

Recognition

forearm — 1.34 to 1.61 inches (3.4 to 4.1 cm)
wingspan — 9.02 to 10.59 inches (22.9 to 26.9 cm)
ears — 0.55 to 0.63 inches (1.4 to 1.6 cm)
foot — approximately 0.39 inches (1.0 cm); long hairs on toes extend beyond claws.

Distribution (Fig. 6a)

Color

Pale tan through reddish brown to dark brown, depending on geographic location. The species is a rich dark brown in the eastern United States and most of the west coast. Fur is glossy and sleek.

Confusion may occur with a few other "house" bat species. In the East, it may be confused with Keen's bat (*M. keenii*), which has longer ears [0.69 to 0.75 inches (1.7 to 1.9 cm)] and a longer, more pointed tragus (the appendage at the base of the ear). In the West, it resembles the Yuma myotis (*M. yumanensis*), which has dull fur and is usually smaller. However, the Yuma myotis and little brown may be indistinguishable in some parts of the northwestern United States where they may hybridize.

Habits

This is one of the most common bats found in and near buildings, often located near a body of water where they forage for insect prey. Summer colonies are very gregarious, commonly roosting in dark, hot attics and associated roof spaces where maternity colonies may include hundreds to a few thousand individuals. Colonies may also form beneath shingles and siding, in tree hollows, beneath bridges, and in caves. Litter size is 1 in the Northeast; twins occasionally occur in some other areas. The roost is often shared with the big brown bat (*E. fuscus*) though the latter is less tolerant of high temperatures; *M. keenii* may also share the same site. Separate groups of males tend to be smaller and choose cooler roosts within attics, behind shutters, under tree bark, in rock crevices, and within caves.

In the winter, little brown bats in the eastern part of their range abandon buildings to hibernate in caves and mines. Such hibernacula may be near summer roosts or up to a few hundred miles (km) away. Little is known of the winter habits of *M. lucifugus* in the western United States.

The life span of little brown bats has been established to be as great as 31 years. The average life expectancy, however, is probably limited to only a few years.

Big brown bat (*Eptesicus fuscus*)

Recognition

forearm — 1.65 to 2.01 inches (4.2 to 5.1 cm)
wingspan — 12.80 to 13.78 inches (32.5 to 35.0 cm)
ears — with rounded tragus

Distribution (Fig. 6b)

Color

From reddish brown, copper colored, to a dark brown depending on geographic location. This is a large bat without distinctive markings.

Confusion may occur with the evening bat (*Nycticeius humeralis)* though the latter is much smaller.

Habits

This hardy, rather sedentary species appears to favor buildings for roosting. Summer maternity colonies may include a dozen or so and up to a few hundred individuals, roosting behind chimneys, in enclosed eaves, in hollow walls, attics, barns, and behind shutters and unused sliding doors. They also form colonies in rock crevices, beneath bridges, in hollow trees, and under loose bark. Litter size is 2 in the East to the Great Plains; from the Rockies westward 1 young is born. *E. fuscus* frequently shares roosts with *M. lucifugus* in the East, and with *M. yumanensis, Taderida*, and *Antrozous* in the West. Males typically roost in smaller groups or alone during the summer.

The big brown bat is one of the most widely distributed of bats in the United States and is probably familiar to more people than any other species. This is partially due to its large, easy-to-observe size, but also to its ability to overwinter in buildings (attics, wall spaces, and basements). Its close proximity to humans, coupled with its tendency to move about when temperature shifts occur, often brings this bat into human living quarters and basements in summer and winter. Big browns also hibernate in caves, mines, storm sewers, burial vaults, and other underground harborage. While *E. fuscus* will apparently travel as far as 150 miles (241 km) to hibernacula, the winter quarters of the bulk of this species are largely unknown.

Big brown bats may live as long as 18 years.

Mexican free-tailed bat (*Tadarida brasiliensis*)

Recognition

forearm — 1.42 to 1.81 inches (3.6 to 4.6 cm)
wingspan — 11.42 to 12.80 inches (29.0 to 32.5 cm); long narrow wings
tail (interfemoral) membrane — does not enclose the lower one-third to one-half of the tail, hence the name free-tailed
foot — long, stiff hairs as long as the foot protrude from the toes.

Distribution (Fig. 6c)

Color

Dark brown or dark gray. Fur of some individuals may have been bleached to a pale brown due to ammonia fumes from urine and decomposing guano.

Confusion is not likely to occur with other species that commonly inhabit human buildings.

Habits

T. brasiliensis forms the largest colonies of any warm-blooded animal, establishing sizable colonies in buildings, particularly on the West Coast and in the Gulf states from Texas east. Hundreds to thousands may be found in buildings or under bridges. It is primarily a cave bat in Arizona, New Mexico, Oklahoma, and Texas; buildings are used as temporary roosts during migrations. Litter size is 1.

Taderida often share roosts with other species. In the West, for example, they may be found in buildings with *A. pallidus*, *M. yumanensis*, and *E. fuscus*. Some males are always present in the large maternity colonies, but they tend to segregate in separate caves.

A few *Taderida* may overwinter in buildings as far north as South Carolina in the East and Oregon in the West. Most of this species migrate hundreds of miles to warmer climes (largely to Mexico) for the winter.

Pallid bat (*Antrozous pallidus*)

Recognition

forearm — 1.89 to 2.36 inches (4.8 to 6.0 cm)
wingspan — 14.17 to 15.35 inches (36.0 to 39.0 cm)
ears — large; widely separated and more than half as broad as long. The ears are nearly half as long as the combined length of the bat's head and body.
eyes — large

Distribution (Fig. 6d)

Color

pale, upper parts are light yellow, the hairs tipped with brown or gray. Underparts are pale creamy, almost white. This large, light-colored bat is relatively easy to recognize.

Confusion with other species that commonly inhabit human buildings is not likely to occur.

Habits

Maternity colony size ranges from about 12 to 100 individuals. Roost sites include buildings, bridges, and rock crevices; less frequently, tree cavities, caves, and mines. Litter size is most commonly 2. The roost is frequently shared with *T. brasiliensis* and *E. fuscus* in the West. While groups of males tend to segregate during the nursery period (sometimes in the same building), other males are found within the maternity colony.

An interesting feature of pallid bats is that they fly close to the ground, may hover, and take most prey on the ground, not in flight. Prey includes crickets, grasshoppers, beetles, and scorpions. They will also forage among tree foliage.

Pallid bats are not known to make long migrations, though little is known of their winter habits.

Yuma myotis (*Myotis yumanensis*)

Recognition

forearm — 1.26 to 1.50 inches (3.2 to 3.8 cm)
wingspan — about 9.25 inches (23.5 cm)
ears — 0.55 to 0.59 inches (1.4 to 1.5 cm)
foot — 0.39 inches (1.0 cm)

Distribution (Fig. 6e)

Color

Light tan to dark brown; underside is whitish to buffy.

Confusion may occur in the West with *M. lucifugus*, though the latter tends to have longer, glossier fur, and is larger. In the Northwest, hybridization occurs with *M. lucifugus*, making the species indistinguishable.

Habits

Maternity colonies, up to several thousand individuals, form in the summer in attics, belfries, under bridges, and in caves and mines. Litter size is 1. Males typically segregate during the nursery period and roost as solitary individuals in buildings and other suitable harborage.

M. yumanensis is more closely associated with water than is any other North American bat species. Nearly all roosts have open water nearby. This species is not as tolerant as *M. lucifugus* of high roost temperatures and will move to cooler niches within a building when temperatures rise much above 100° F (37.8° C).

M. yumanensis abandons maternity colonies in the fall, but its winter habitat is not known.

Evening bat (*Nycticeius humeralis*)

Recognition

forearm — 1.30 to 1.54 inches (3.3 to 3.9 cm)
wingspan — 10.24 to 11.02 inches (26.0 to 28.0 cm)
ears — with short, curved, and rounded tragus

Confusion may occur with the big brown bat (*E. fuscus*), which can be readily distinguished by its larger size. It bears some resemblance to the somewhat smaller little brown bat (*M. lucifugus*) but can be identified by its characteristic blunt tragus.

Distribution (Fig. 6f)

Color

Medium brown with some variation to yellow-brown in subtropical Florida. No distinctive markings.

Habits

Summer maternity colonies in buildings may consist of hundreds of individuals. Litter size is usually 2. Colonies also form in tree cavities and under loose tree bark. In the Southeast, *T. brasiliensis* commonly inhabits the same building with *N. humeralis*. This is one of the most common bats in towns throughout the southern coastal states. Very little is known about this species, and virtually nothing is known of its winter habitat except that it almost never enters caves.

Solitary Bats

Keen's bat (*Myotis keenii*)

Recognition

forearm — 1.26 to 1.54 inches (3.2 to 3.9 cm)
wingspan — 8.98 to 10.16 inches (22.8 to 25.8 cm)
ears — 0.67 to 0.75 inches (1.7 to 1.9 cm); with a long, narrow, pointed tragus

Distribution (Fig. 6g)

Color

Brown, but not glossy; somewhat paler in the East.

Confusion may occur with *M. lucifugus,* which has glossy fur, shorter ears, and does not have the long, pointed tragus.

Habits

Excluding small maternity colonies (up to 30 individuals are on record), *M. keenii* are generally found singly in the East. Roosting sites include: behind shutters, under wooden shingles, sheltered entryways of buildings, in roof spaces, in barns, and beneath tree bark. In the West, this bat is known as a solitary species, roosting in tree cavities and cliff crevices. Litter size is probably 1. The roost is sometimes shared with *M. lucifugus*. The sexes probably segregate during the nursery period. In winter, these bats hibernate in caves and mines.

Red Bat (*Lasiurus borealis*)

Recognition

forearm — 1.38 to 1.77 inches (3.5 to 4.5 cm)
wingspan — 11.42 to 13.07 inches (29.0 to 33.2 cm); long, pointed wings
ears — short rounded
tail membrane — heavily furred on upper surface, with a distinctive long tail.

Distribution (Fig. 6h)

Color

Bright orange to yellow-brown; usually with a distinctive white mark on the shoulders.

Confusion may occur with the hoary bat (*L. cinereus*), which is frosted-gray in appearance and larger.

Habits

Red bats live solitary lives, coming together only to mate and migrate. Few people are familiar with this species. They typically spend summer days hidden in the foliage of deciduous trees. The number of young ranges from 1 to 4, averaging 2.3.

These bats often chase insects that are attracted to lights, such as street lamps. It is this behavior that most likely brings them in close proximity to people.

L. borealis is well-adapted for surviving drastic temperature fluctuations; it does not hibernate in caves, but apparently in trees. Some migrate long distances. During migration, red bats have been known to land on high-rise buildings and on ships at sea.

Silver-haired bat (*Lasionycteris noctivagans*)

Recognition

forearm — 1.46 to 1.73 inches (3.7 to 4.4 cm)
wingspan — 10.63 to 12.20 inches (27.0 to 31.0 cm)
ears — short, rounded, hairless
tail membrane — upper surface is sparsely furred on the anterior one-half.

Distribution (Fig. 6i)

Color

Usually black with silver-tipped fur; some individuals with dark brown, yellowish-tipped fur.

Confusion sometimes occurs with the larger hoary bat (*Lasiurus cinereus*), which has patches of hair on the ears and wings, heavy fur on the entire upper surface of the tail membrane, and has a distinctive throat "collar."

Habits

The silver-haired bat roosts in a wide variety of harborages. A typical roost might be behind loose tree bark; other sites include tree hollows and bird nests. This species is solitary except when with young. Additionally, there are unconfirmed reports that it is sometimes colonial (Dalquest and Walton 1970) and may roost in and on buildings. The litter size is 2. The sexes segregate through much of the summer range.

L. noctivagans hibernates in tree crevices, under loose bark, in buildings (including churches, sky scrapers, and wharf houses), hulls of ships, rock crevices, silica mines, and non-limestone caves. It also may migrate, during which time it is encountered in buildings (they favor open sheds, garages, and outbuildings rather than enclosed attics), in lumber piles, and on ships at sea.

Hoary bat (*Lasiurus cinereus*)

Recognition

forearm — 1.81 to 2.28 inches (4.6 to 5.8 cm)
wingspan — 14.96 to 16.14 inches (38.0 to 41.0 cm)
ears — relatively short, rounded, edged with black, and with fur
tail membrane — completely furred on upper surface

Distribution (Fig. 6j)

Color

Dark, but many hairs are tipped in white, giving it a frosted appearance. This bat also has a yellowish or orangish throat "collar."

Confusion may sometimes occur with the much smaller silver-haired bat (*Lasionycteris noctivagans*), which lacks the fur patches and markings on the ears, markings on the throat, and has a tail membrane that is only lightly furred on the upper surface.

Habits

Hoary bats generally spend summer days concealed in tree foliage (often in evergreens), rarely enter houses, and are not commonly encountered by people. *L. cinereus* at their day roosts are usually solitary except when with young. The litter size is 2. The sexes segregate through most of the summer range.

This is one of the largest bats in North America, a powerful flier, and an accomplished migrant. Records indicate that some *L. cinereus* may hibernate in northern parts of their range.

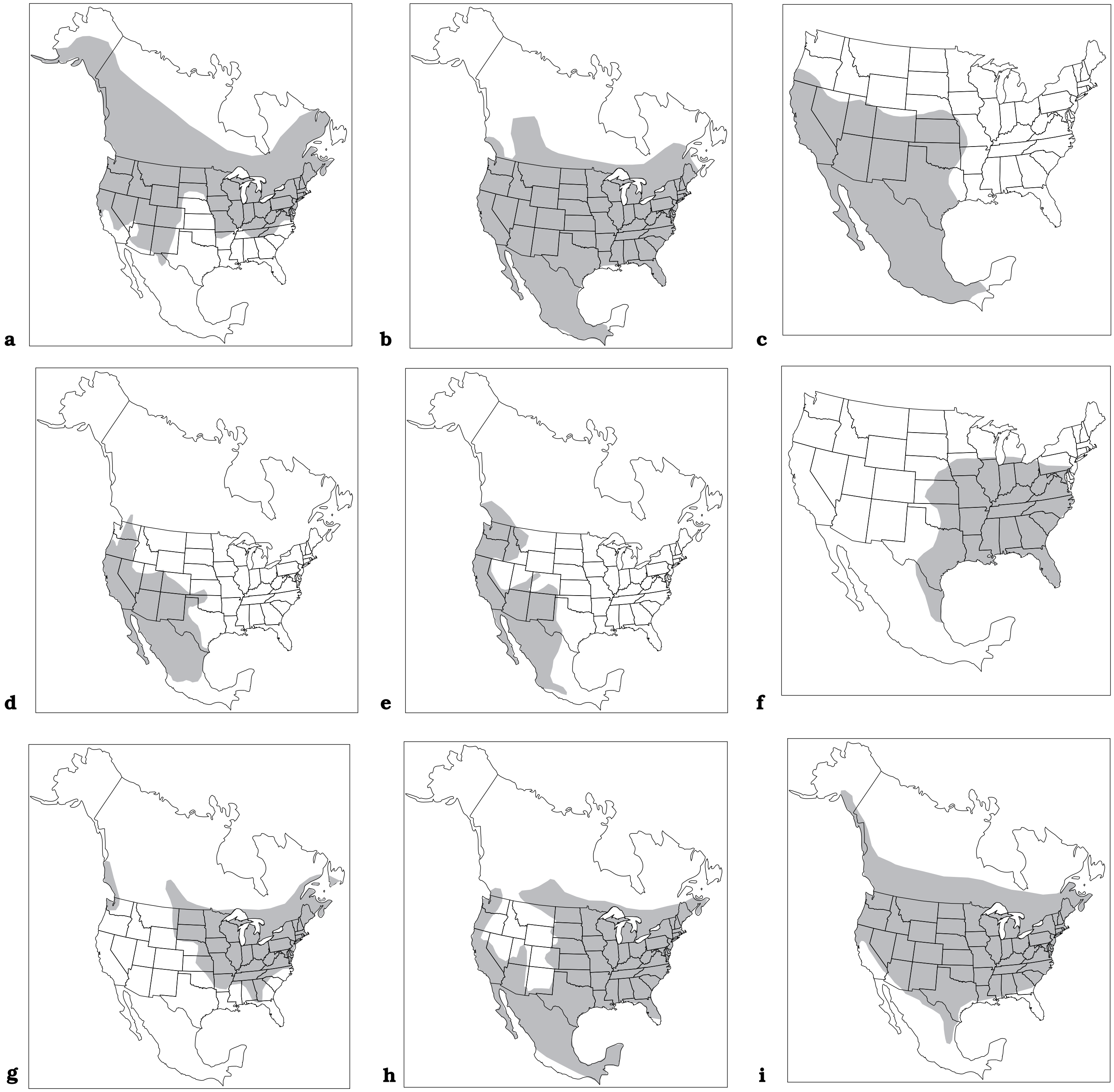

Figure 6. Distributions of selected bat species in North America: (a) little brown bat, (b) big brown bat, (c) Mexican free-tailed bat, (d) pallid bat, (e) Yuma myotis, (f) evening bat, (g) Keen's bat, (h) red bat, (i) silver-haired bat, (j) hoary bat.

Food Habits

Bats in North America are virtually all insectivorous, feeding on a variety of flying insects (exceptions among house bats were noted previously). Many of the insects are harmful to humans. While there must be some limitations based on such factors as bats' body size, flight capabilities, and jaw opening, insectivorous bats apparently consume a wide range of prey (Barbour and Davis 1979). The little brown bat's diet includes mayflies, midges, mosquitoes, caddis flies, moths, and beetles. It can consume insects equal to one-third of its body weight in 1/2 hour of foraging. The big brown bat may fill its stomach in about 1 hour (roughly 0.1 ounce per hour [2.7 g/hr]) with prey including beetles, moths, flying ants, true bugs, mayflies, caddis flies, and other insects. The nightly consumption of insects by a colony of bats can be extremely large.

General Biology, Reproduction, and Behavior

Most North American bats emit high frequency sounds (ultrasound) inaudible to humans and similar to sonar, in order to avoid obstacles, locate and capture insect prey, and to communicate. Bats also emit audible sounds that may be used for communication between them.

Bats generally mate in the fall and winter, but the female retains the sperm in the uterus until spring, when ovulation and fertilization take place. Pregnant females may congregate in maternity colonies in buildings, behind chimneys, beneath bridges, in tree hollows, caves, mines, or other dark retreats. No nests are built. Births typically occur from May through July. Young bats grow rapidly and are able to fly within 3 weeks. Weaning occurs in July and August, after which the nursery colonies disperse.

Bats prepare for winter around the time of the first frost. Some species migrate relatively short distances, whereas certain populations of the Mexican free-tailed bat may migrate up to 1,000 miles (1,600 km). Bats in the northern United States and Canada may hibernate from September through May. Hibernation for the same species in the southern part of their range may be shorter or even sporadic. Some may fly during warm winter spells (as big brown bats may in the northeastern part of the United States). Bats often live more than 10 years.

In response to a variety of human activities, direct and indirect, several bat species in the United States have declined in number during the past few decades. Chemical pesticides (particularly the use of persistent and bioaccumulating organic pesticides) have decreased the insect supply, and contaminated insects ingested by bats have reduced bat populations. Many bats die when people disturb summer maternity roosts and winter hibernacula. Vandals and other irresponsible individuals may deliberately kill bats in caves and other roosts. Even the activities of speleologists or biologists may unintentionally disturb hibernating bats, which depletes fat reserves needed for hibernation.

Modification and destruction of roost sites has also decreased bat numbers. Sealing and flooding of mineshafts and caves and general quarrying operations may inadvertently ruin bat harborages. Forestry practices have reduced the number of hollow trees available. Some of the elimination of natural bat habitat may contribute to bats roosting in buildings.

Damage and Damage Identification

Bat Presence

Bats often fly about swimming pools, from which they drink or catch insects. White light (with an ultraviolet component), commonly used for porch lights, building illumination, street and parking-lot lights, may attract flying insects, which in turn attract bats. Unfortunately, the mere presence of a bat outdoors is sometimes beyond the tolerance of some uninformed people. Information is a good remedy for such situations.

Bats commonly enter buildings through openings associated with the roof edge and valleys, eaves, apex of the gable, chimney, attic or roof vent, dormers, and siding (see Fig. 7). Other

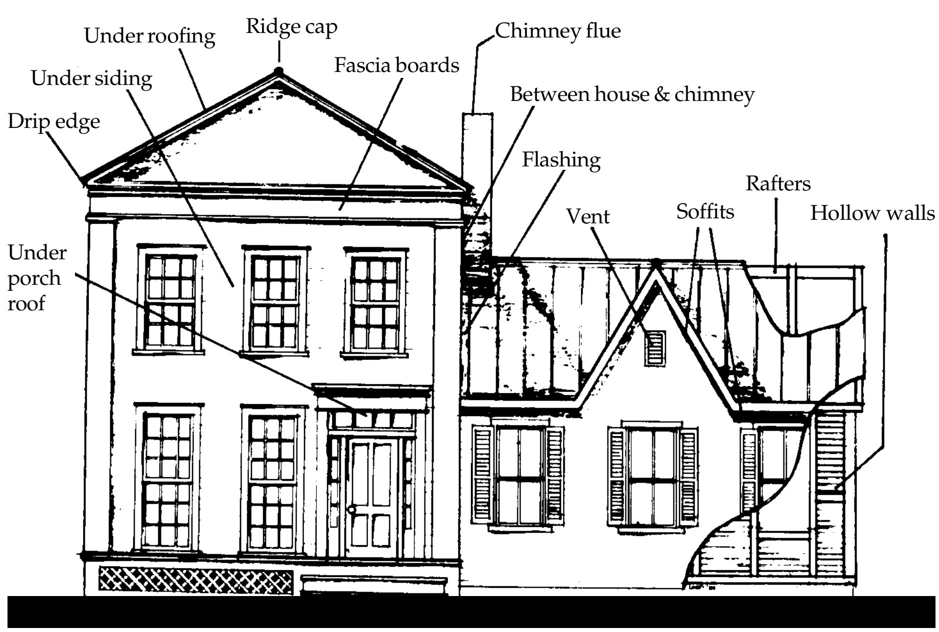

Fig. 7. Common points of entry and roosting sites of house bats.

openings may be found under loose-fitting doors, around windows, gaps around various conduits (wiring, plumbing, air conditioning) that pass through walls, and through utility vents.

Bats are able to squeeze through narrow slits and cracks. For purposes of bat management, one should pay attention to any gap of approximately 1/4 x 1 1/2 inches (0.6 x 3.8 cm) or a hole 5/8 x 7/8 inch (1.6 x 2.2 cm). Such openings must be considered potential entries for at least the smaller species, such as the little brown bat. The smaller species require an opening no wider than 3/8 inch (0.95 cm), that is, a hole the diameter of a US 10-cent coin (Greenhall 1982). Openings of these dimensions are not uncommon in older wood frame structures where boards have shrunk, warped, or otherwise become loosened.

The discovery of one or two bats in a house is a frequent problem. In the Northeast, big brown bats probably account for most sudden appearances (see Figs. 3 and 8). Common in urban areas, they often enter homes through open windows or unscreened fireplaces. If unused chimneys are selected for summer roosts, bats may fall or crawl through the open damper into the house. Sometimes bats may appear in a room, then disappear by crawling under a door to another room, hallway, or closet. They may also disappear behind curtains, wall hangings, bookcases, under beds, into waste baskets, and so forth. Locating and removing individual bats from living quarters can be laborious but is important. If all else fails, wait until dusk when the bat may appear once again as it attempts to find an exit. Since big brown bats may hibernate in the cooler recesses of heated buildings, they may suddenly appear (flying indoors or outdoors) in midwinter during a warm spell or a cold snap as they move about to adjust to the temperature shift.

Roosting Sites

Bats use roosting niches that are indoors (human dwellings, outbuildings, livestock quarters, warehouses), semi-enclosed (loading docks, entrance foyers), partially sheltered (porches, carports, pavilions, highway underpasses, bridges), and open structural areas (window shutters, signs). Once there, active bats in and on buildings can have several economic and aesthetic effects, often intertwined with public health issues (Frantz, 1988). Unusual roosting areas include wells, sewers, and graveyard crypts. Before considering control measures, verify that bats are actually the cause of the problem.

Rub Marks

Surface areas on walls, under loose woodwork, between bricks and around other bat entryways often have a smooth, polished appearance. The stained area is slightly sticky, may contain a few bat hairs, and is yellow-brown to blackish brown in color. The smooth gloss of these rub marks is due to oils from fur and other bodily secretions mixed with dust, deposited there as many animals pass repeatedly for a long period over the same surface. Openings marked in this way have been used heavily by bats.

Noise

Disturbing sounds may be heard from vocalizations and grooming, scratching, crawling, or climbing in attics, under eaves, behind walls, and between floors. Bats become particularly noisy on hot days in attics, before leaving the roost at dusk, and upon returning at dawn. Note that rustling sounds in chimneys may be caused by birds or raccoons and scratching and thumping sounds in attics and behind walls may indicate rats, mice, or squirrels.

Guano and Urine

Fecal pellets indicate the presence of animals and are found on attic floors, in wall recesses, and outside the house at its base. Fecal pellets along and inside walls may indicate the presence of mice, rats, or even roaches. Since most house bats north of Mexico are insectivorous, their droppings are easily distinguished from those of small rodents. Bat droppings tend to be segmented, elongated, and friable. When crushed, they become powdery and reveal shiny bits of undigested insect remains. In contrast, mice and rat droppings tend to taper, are unsegmented, are harder and more fibrous, and do not become powdery when crushed (unless extremely aged).

The droppings of some birds and lizards may occasionally be found along with those of bats. However, bat droppings never contain the white chalky material characteristic of the feces of these other animals.

Bat excrement produces an unpleasant odor as it decomposes in attics, wall spaces, and other voids. The pungent, musty, acrid odor can often be detected from outside a building containing a large or long-term colony. Similar odor problems occur when animals die in inaccessible locations. The odor also attracts arthropods which may later invade other areas of a building.

Bat guano may provide a growth medium for microorganisms, some of which are pathogenic (histoplasmosis, for example) to humans. Guano accumulations may fill spaces between walls, floors, and ceilings. It may create a safety hazard on floors, steps, and ladders, and may even collapse ceilings. Accumulations also result in the staining of ceilings, soffits, and siding, producing unsightly and unsanitary conditions.

Bats also urinate and defecate in flight, causing multiple spotting and staining on sides of buildings, windows, patio furniture, automobiles, and other objects at and near entry/exit holes or beneath roosts. Bat excrement may also contaminate stored food, commercial products, and work surfaces.

Bat urine readily crystallizes at room temperature. In warm conditions under roofs exposed to sun and on chimney walls, the urine evaporates so quickly that it crystallizes in great accumulations. Boards and beams saturated with urine acquire a whitish powderlike coating. With large numbers of bats, thick and hard stalactites and stalagmites of crystallized bat urine are occasionally formed.

Although the fresh urine of a single bat is relatively odorless, that of any moderate-sized colony is obvious, and the odor increases during damp weather. Over a long period of time urine may cause mild wood deterioration (Frantz and Trimarchi 1984). As the urine saturates the surfaces of dry wood beams and crystallizes, the wood fibers expand and separate. These fibers then are torn loose by the bats crawling over such surfaces, resulting in wood fibers being mixed with guano accumulations underneath.

The close proximity of bat roosts to human living quarters can result in excreta, animal dander, fragments of arthropods, and various microorganisms entering air ducts as well as falling onto the unfortunate residents below. Such contaminants can result in airborne particles of public health significance (Frantz 1988).

Ectoparasites and other Arthropods

Several arthropods (fungivores, detritivores, predators, and bat ectoparasites) are often associated with colonies of bats in buildings. Their diversity depends on the number of bats, age and quantity of excreta deposits, and season. Arthropods such as dermestid beetles (*Attagenus megatoma)* contribute to the decomposition of guano and insect remnants, but may also become a pest of stored goods and/or a nuisance within the living quarters. Cockroaches (for example, *Blatta orientalis*) attracted to guano may invade other parts of a building. Bat bugs (*Cimex* spp.) are sometimes found crawling on the surface of beams or around holes leading to secluded recesses used by bats. Bat ectoparasites (ticks, mites, fleas, and bugs) rarely attack humans or pets and quickly die in the absence of bats. Ectoparasites may become a nuisance, however, following exclusion of large numbers of bats from a well-established roost site. Area fumigation with a total release pyrethrum-based aerosol may be an appropriate solution for arthropod knockdown within an enclosed space, but only after bats have departed. For long-term arthropod control, lightly dust appropriate surfaces (affected attic beams, soffits) with boric acid powder or diatomaceous earth; carefully read all product labels before using any pesticide. Note that neither rabies nor Lyme disease is transmitted by any arthropods associated with bats.

Public Health Issues

Rabies—*General Epidemiology.* Bats are distinct from most vertebrate pests that inhabit human dwellings because of the potential for transmitting rabies — a viral infection of mammals that is usually transmitted via the bite of an infected animal. Rabies does not respond to antibiotic therapy and is nearly always fatal once symptoms occur. However, because of the long incubation period (from 2 weeks to many months), prompt vaccination following exposure can prevent the disease in humans. Dogs, cats, and livestock also can be protected by periodic vaccinations.

Bats are not asymptomatic carriers of rabies. After an incubation period of 2 weeks to 6 months, they become ill with the disease for as long as 10 days. During this latter period, a rabid bat's behavior is generally not normal—it may be found active during the daytime or on the ground incapable of flying. Most human exposures are the result of accidental or careless handling of grounded bats. Even less frequently, bats in this stage of illness may be involved in unprovoked attacks on people or pets (Brass, pers. commun.; Trimarchi et al. 1979). It is during this stage that the rabid bat is capable of transmitting the disease by biting another mammal. As the disease progresses the bat becomes increasingly paralyzed and dies as a result of the infection. The virus in the carcass is reported to remain infectious until decomposition is well advanced.

Significance. Rabies is the most important public health hazard associated with bats. Infection with rabies has been confirmed in all 40 North American species of bats that have been adequately sampled in all of the contiguous United States and in most provinces of Canada. Figure 8 shows the frequency of bat species submitted for rabies testing in New York State over the last 12 years. While not a nationwide measure of human encounters with bats, Figure 8 illustrates that bat species are not encountered equally. Note that bats submitted for testing are often ill and/or easily captured. The numbers and species encountered will vary with the region of the country; data are generally available from local and state health authorities.

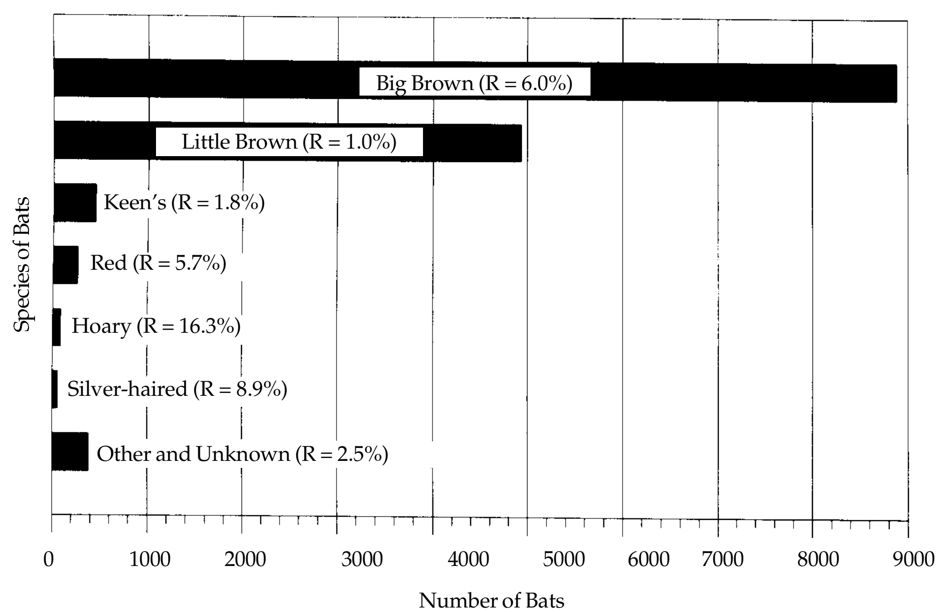

Fig. 8. Profile of bat species submitted to the New York State Rabies Laboratory, 1981-1992.

Random sampling of bats (healthy and ill) indicates an overall infection rate of less than 1%. Finding a rabid bat in a colony does not imply that the remaining animals are rabid. In fact, the probability of immediately finding more than one additional infected bat in that colony is small.

Bats rank third (behind raccoons and skunks) in incidence of wildlife rabies in the United States (Krebs et al. 1992). In the last 20 years, however, there have been more human rabies cases of bat origin in the United States than of any other wildlife group. Furthermore, the disease in bats is more widely distributed (in all 48 contiguous states in 1989) than in any other species. In Canada, bats also rank third (behind foxes and skunks) in the incidence of wildlife rabies. Therefore, every bat bite or contact must be considered a potential exposure to rabies. While aerosol transmission of the rabies virus from bats in caves to humans and some other mammals has been reported, this is not a likely route of infection for humans entering bat roosts in buildings in temperate North America. Note that vampire bats are not a threat north of Mexico.

Histoplasmosis—*General Epidemiology.* Histoplasmosis is a very common lung disease of worldwide distribution caused by a microscopic fungus, *Histoplasma capsulatum*. *Histoplasma* exists in nature as a saprophytic mold that grows in soil with high nitrogen content, generally associated with the guano and debris of birds (particularly starlings, *Sturnus vulgaris*, and chickens) and bats. Wind is probably the main agent of dispersal, but the fungus can survive and be transmitted from one site to another in the intestinal contents of bats, and also in the dermal appendages of both bats and birds. The disease can be acquired by the casual inhalation of windblown spores, but infections are more likely to result from visits to point sources of growth of the fungus. Relative to bats, such sources include bat roosts in caves, barns, attics, and belfries, and soil enriched with bat guano.

Numerous wild and domestic animals are susceptible to histoplasmosis, but bats (and perhaps the armadillo) are the only important animal vectors. Unlike bats, birds do not appear to become infected with the fungus. Both the presence of guano and particular environmental conditions are necessary for *H. capsulatum* to proliferate. In avian habitats, the organism apparently grows best where the guano is in large deposits, rotting and mixed with soil rather than in nests or in fresh deposits. Specific requirements regarding bats have not been described, though bat roosts with long-term infestation are often mentioned in the literature.

While histoplasmosis in the United States is particularly endemic to the Ohio-Mississippi Valley region (which is also an area with the greatest starling concentration) and areas along the Appalachian Mountains, it is also found in the lake and river valleys of other states. Outside areas with "appropriate" environmental conditions, there also occur scattered foci with high infection rates usually associated with caves inhabited by bats or birds.

Significance. When soil or guano containing *H. capsulatum* is physically disturbed, the spores become airborne. Persons at particular risk of histoplasmosis of bat origin include spelunkers, bat biologists, pest control technicians, people who clean out or work in areas where bats have habitually roosted, and people in contact with guano-enriched soil — such as around the foundation of a building where guano has sifted down through the walls.

Infection occurs upon inhalation of spores and can result in a variety of clinical manifestations; severity partially depends on the quantity of spores inhaled. The infection may remain localized in the lungs where it may resolve uneventfully; this is the case for about 95% of the 500,000 infections occurring annually in the United States. Such infections are identified only by the presence of a positive histoplasmin skin test and/or calcified lesions on routine radiographs. Other individuals may have chronic or progressive lung disease requiring treatment. Less severe forms of these infections may be accompanied by fever, cough, and generalized symptoms similar to a prolonged influenza. Resolution of the disease confers a degree of immunity to reinfection. In addition, resolution confers varying degrees of hypersensitivity to *H. capsulatum*; as a consequence, massive reinfection in highly sensitized lungs may result in a fatal acute allergic reaction.

In a small percentage of chronic histoplasmosis cases, the fungus disseminates to involve multiple organ systems and may be fatal. This form is usually seen in young children (1 year or older) and in immunocompromised adults. In recent years, systemic infections have been increasing in frequency globally as an opportunistic infection of AIDS patients.

Legal Status

The lethal control of bats, even when there is a proven potential danger to humans, often is subjected to careful scrutiny and interagency coordination. A survey of federal legislative actions, court decisions, and agency interpretations concerning bats can be found in *Bat Management in the United States* (Lera and Fortune 1979).

Some states have laws that specifically mention bats, either providing or denying protection. Others have legislation that applies to bats only by interpretation, since bats may be considered nongame wildlife or indigenous state mammals. Some bats have protection as either federal or state-listed endangered species, but the same state may not protect other species of bats. Enforcement and public education must accompany legislation to accomplish the intended goal of protecting the public and saving endangered bats. Familiarity with the appropriate federal and state laws should precede any nuisance management activities.

Damage Prevention and Control Methods

Premanagement Considerations

Bat Watch for Infestation Confirmation. To confirm that bats are actually roosting in or on a building, look for bats flying in and out of a site and/or for signs of infestation. A bat watch can be conducted by two people (more may be necessary to observe large or complex sites) posted at opposite corners of a structure. An evening watch begins about 30 minutes before dark and a morning watch begins about 1 hour before dawn. Observations should continue for approximately 1 hour.

Such observations can indicate exit/entry points and the number of bats. With practice, distinguishing some bat species may also be possible. For example, compared to the big brown bat, the little brown bat is noticeably smaller in size, and its flight has more rapid wing beats, and more rapid turning and darting.

It may be necessary to watch for more than one night to compensate for weather conditions, bats' sensitivity to observers, noisy or inexperienced observers, and improper use of light. Observations can be enhanced with a standard flashlight, but be certain to keep the bright part of the beam as far as possible away from the exit hole being observed. Bright light will increase bats' reluctance to exit and may result in an incomplete exit of the colony. A valuable observation aid is a powerful, rechargeable flashlight equipped with a plastic, red pop-off filter (similar to the Kodak Wratten 89B). Also, an electric headlamp, supplied with rechargeable batteries and fitted to a climbing or spelunking helmet, allows hands-off illumination outdoors as well as indoors when exploring roost locations. Bats are sensitive to light intensity and can visually discriminate shapes and patterns in extremely low light situations. They can only see in black and white; hence, the low-contrast illumination and soft shadows produced by red light has little effect on bats.

Locating the Roost(s). It is not always possible or convenient to conduct a bat watch. Thus, a detailed inspection inside the building for bats or bat sign may be necessary to find specific roosts. Daytime is best, especially during the warmer part of the day. Bats roost in the most varied kinds of buildings and in every part from cellar to attic. Some types of buildings appear preferable (older houses, churches, barns, proximity to water) as do certain roost locations therein, especially areas with little disturbance, low illumination, little air circulation, and high temperatures. Often it is easy to locate bats, especially in warm weather in attics or lofts, where they may hang in clusters or side-by-side from the sloping roof lath, beams, and so forth. However, bats have the ability to find crevices and cavities, and if disturbed may rapidly disappear into the angles between converging beams, behind such beams or wallboards, into mortise holes on the underside of beams, and into the multilayered wall and roof fabrications. If bats cannot be openly observed, usually there are various interior and exterior signs of their presence. Often there are multiple roost sites within or on a single building.

Problem Assessment. Once it has been confirmed that bats are present, one must determine if there is damage, if there is a health risk, and if some intervention is warranted. There are circumstances in which "no action" is the correct action because of the beneficial role of bats. In cases where there is risk of contact, damage from excreta accumulations, stains, and so on, intervention may be necessary.

Timing. With the exception of disease treatment and removal of the occasional bat intruder, timing becomes an important planning consideration. Management procedures must not complicate an already existing problem and should emphasize bat conservation. Therefore, all interventions should be initiated before the young are born or after they are weaned and able to fly. Thus, the annual opportunity extends from about mid-August to mid-May for much of North America. Treatments might otherwise result in the unnecessary death of animals (especially young unable to fly) trapped inside, offensive odors, and attraction of arthropod scavengers.

Disease Considerations

Rabies — *Preventive Measures.* It should be noted that newspapers, television, and other mass media sometimes misrepresent the role of rabid bats as a risk to humans. However, the unfortunate recent (1983 to 1993) deaths of a 22-year-old man in Texas, a 30-year-old bat scientist in Finland, a university student in British Columbia, a 5-year-old girl in Michigan, a man in Arkansas, an 11-year-old girl in New York, and a woman in Georgia amply underscore the need to pay prompt attention to bat bites and other exposures.

Many rabies exposures could be avoided if people simply refrained from handling bats. Adults and children should be strongly cautioned never to touch bats with bare hands. All necessary measures should be taken to ensure that bats cannot enter living quarters in houses and apartments. Pet cats and dogs should be kept up-to-date in rabies vaccinations. This is also true for pets confined indoors, because contact with bats frequently occurs indoors. Valuable livestock also should be vaccinated if kept in buildings harboring bats or if in a rabies outbreak area (NASPHV 1993). While transmission of rabies from bats to terrestrial mammals apparently is not common, such incidents have been reported (Reid-Sanden et al. 1990, Trimarchi 1987). Dogs, cats, and livestock that have been exposed to a rabid or suspected-rabid animal, but are not currently vaccinated, must be either quarantined or destroyed.

Lastly, pest control technicians, nuisance wildlife control personnel, wildlife biologists, and other individuals at particular risk of contact with rabid bats (or other wildlife) should receive a rabies pre-exposure vaccination. This effective prophylaxis involves only three injections of rabies vaccine, which are administered in the arm during a month's time.

Rabies — *Treatment for Exposure.* If a person is bitten or scratched by a bat, or there is any suspicion that bat saliva or nervous tissue has contaminated an open wound or mucous membrane, wash the affected area thoroughly with soap and water, capture the bat without damaging the head, and seek immediate medical attention. The incident should be reported promptly to local health authorities in order to arrange rabies testing of the bat.

If the bat is captured and immediate transportation to the testing laboratory is possible, and if immediate testing can be arranged, postexposure treatment may be delayed several hours until the test results are known. Postexposure prophylaxis must be administered immediately, however, if the bat cannot be captured, if prompt transportation to the laboratory is not possible, if the specimen is not suitable for reliable diagnosis, or if the test results prove positive for rabies.

The prophylaxis has little resemblance to that of many years ago. Today, it consists of one dose of rabies immune globulin (human origin) and one dose of rabies vaccine (human diploid cell) administered preferably on the day of exposure, followed by additional single doses of rabies vaccine on days 3, 7, 14, and 28 following the initial injection. This treatment is normally safe, relatively painless, and very effective.

Histoplasmosis — *Preventive Measures.* Histoplasmosis can most easily be prevented by avoiding areas that harbor *H. capsulatum*. Since this is not practical for individuals who must work in and around active/inactive bat roosting sites, other measures can be recommended to reduce the risk of infection during cleaning, field study, demolition, construction, and other activities.

Persons working in areas known or suspected to be contaminated with *H. capsulatum* should always wear protective masks capable of filtering out particles as small as 2 microns in diameter or use a self-contained breathing apparatus. In areas known to be contaminated, wear protective clothing and gloves that can be removed at the site and placed in a plastic bag for later decontamination via formalin and washing. Also, clean footwear before leaving the site to prevent spore dissemination in cars, the office, at home, and elsewhere.

Guano deposits and guano-enriched soils should not be unnecessarily disturbed. Dampening with water or scheduling outdoor work at a time when the ground is relatively wet will minimize airborne dust. Chemically decontaminate known infective foci with a spray of 3% formalin (see CDC 1977). To protect the environment, decontamination must be conducted in accordance with state and local regulations. Chemical decontamination of an "active" bat roost should be conducted only after the bats have been excluded or after bats have departed for hibernation.

Histoplasmosis — *Treatment.* Most infections in normally healthy individuals are benign and self-limiting and do not require specific therapy (George and Penn 1986; Rippon 1988). Treatment with an antifungal agent may be prescribed in more severe cases; amphotericin B and/or oral imidazole ketoconazole are typically recommended depending on the specific nature of the infection.

Removal of Occasional Bat Intruders

A bat that has blundered into the living quarters of a house will usually find its way out by detecting air movement. When no bite or contact with people or pets has occurred, the simplest solution for "removing" the bat is to try to confine it to one room, then open windows and doors leading outdoors and allow it to escape. If the bat is present at night, the lights should be dimmed to allow the animal to find open doors and windows; some light is necessary if an observer is to insure that the bat finds its way out. If bright lights are kept on, the bat may become confused and may seek refuge behind shelving, curtains, hanging pictures, or under furniture.

Healthy bats normally will not attack people even when chased. Chasing a flying bat with a folded newspaper, tennis racket, or stick will cause the bat to take evasive action, and a bat's flight reversal to avoid a wall is often misinterpreted as an attack. These flailings, often futile, will cause a bat to seek safety wherever possible, making escape more difficult for the bat and more frustrating for the human.

If the bat has difficulty escaping, it can be captured in a hand net (for example, an insect net [Fig. 9]). Otherwise,

Fig. 9. Using an insect net to remove a bat from a building.

wait for it to come to rest, quickly cover it with a coffee can or similar container, and slide a piece of cardboard or magazine under the can to trap the bat inside (NYSDH 1990). Take the captured bat outdoors and release it away from populated areas, preferably after dark. Note that reasonably thick work gloves should be worn at all times when trying to capture a bat. Also, if a bite or physical contact occurs, capture the bat without damaging its head and immediately contact a physician (see previous section regarding rabies treatment). Management of problems involving bat colonies require more complicated procedures and a greater time commitment.

Exclusion

Preventive Aspects. The most satisfactory and permanent method of managing nuisance bats is to exclude them from buildings. Locate bats and their points of exit/entry through bat watches or other inspection methods. This is a tedious process to locate all openings in use, and bats may switch to alternate ones when normal routes become unavailable. Thus, consider "potential" as well as "active" points of access.

Often it is apparent where bats might gain entrance even when such openings are not directly observable. By standing in various locations of a darkened attic during daylight hours, one often can find leaks of light at the extreme parts of eaves, in layers of subroofing, and below chimney flashings. Seal all gaps of 1/4 x 1 1/2 inches (0.6 x 3.8 cm) and openings 5/8 x 7/8 inch (1.6 x 2.2 cm) or greater.

Bats will also use some of the same obscure holes in buildings through which heat (or cooled air) is lost; thus, bat-proofing often conserves energy. Simple, homemade devices can be used to locate air leaks. Bathroom tissue or very thin plastic film bags can be taped to a clothes hanger. When placed in front of an area with an air leak (for example, around window frames and sashes where caulking or weatherstripping are needed), the tissue or plastic will wave and flutter from air movements (Fig. 10). Indoor air leaks can be found easily by the use of an air flow indicator (Fig. 11). Small-volume smoke generators can be used to locate openings in the floor, ceiling, attic, and basement. Obscure openings also may be located from outside the house by activating smoke candles or smoke bombs (as within an attic), which will produce easily observed dense smoke. Be careful of any fire hazards.

The easiest time to seal bats out of buildings in northern latitudes is during the cooler part of the year when colonies are not resident. During this period, many homeowners need to be reminded that bats, and bat problems, return each summer. Basic carpentry, masonry, and tinsmith skills are valuable in bat exclusion and other pestproofing interventions.

Devices and Methods. Exclusion becomes "denial of reentry" once the bats have returned to establish maternity colonies (and before the young are born), usually from April through mid-May in the Northeast. Denial of reentry is also appropriate anytime after mid-August when young are capable of flying, as long as bats continue to utilize the roost.

Fig. 10. Using a clothes hanger/plastic film combination to detect air leaks.

The traditional way to exclude bats from an occupied roost involves five basic steps: (1) identify and close all indoor openings through which bats might gain access to human living quarters; (2) close most confirmed and all unused potential exterior exits, leaving only a few major openings (it's best to complete this within 1 to 2 days); (3) at night shortly after the bats

Fig. 11. Smoke from the Sensidyne Air Indicator makes it possible to visually determine the directional pattern of air currents.

have departed to feed, temporarily close the few remaining, major exits; (4) check the roost for presence of bats and, if any remain, unplug the temporarily closed exits early the next evening to allow the bats to escape, then temporarily replug the exits (it may be necessary to repeat this step more than once); and (5) when the bats are all out, permanently seal the holes (Frantz and Trimarchi 1984, Greenhall 1982).

Patience and timing are very important in this process. Much of this work can be done during daylight hours except steps 3 and 4, which require climbing on ladders and roofs at night, sometimes with bats flying nearby. The danger of such work is obvious and discouraging.

Some of these difficulties have been overcome by use of the Constantine one-way valvelike device which is installed in the last exit(s) during the day, and permits bats to leave after dark but prevents their reentry (Constantine 1982). Eventually the valve should be removed and the hole(s) sealed. Another device, the EX-100 Hanks Bat Excluder, consists of a piece of nylon window screening, a wooden plate with a hole in the middle to which is attached a one-way plastic flappervalve, and a rigid plastic mesh cone (Anon. 1983). The screening, to which the wooden plate is attached, is used to cover an opening that bats use to exit a building. Both devices are designed to be used on the last few exit points. Installation instructions are available, and properly applied they will undoubtedly exclude bats from relatively small, discrete openings.

The devices of Constantine and Hanks involve a one-way, self-closing valve feature and can be readily installed during daylight hours. Such devices are not readily adaptable to situations with large, diffuse and/or widely distributed entryways. Also, bats can be inadvertently trapped inside if an important exit hole is mistakenly identified as a minor one and is sealed in an attempt to limit the number of holes requiring an exclusion device.

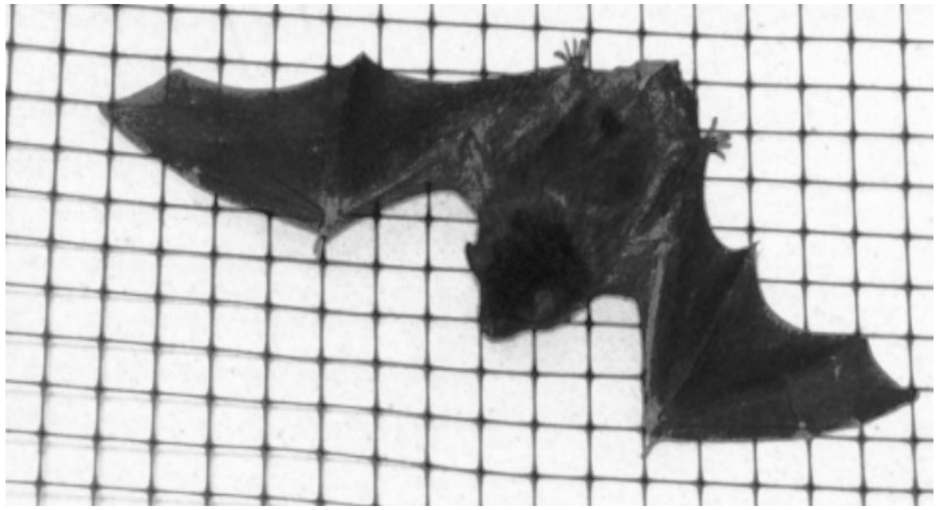

Fig. 12. Bat on birdnetting showing size relationships.

To overcome difficulties with exclusion devices, Frantz' checkvalve was developed using netting made of durable black polypropylene resin (Frantz 1984, 1986). Quality of product is important since the netting should not fray or become misshapen under hot summer conditions. Use only structural grade material that has openings no larger than 1/2 x 1/2 inch (1.3 x 1.3 cm), weighs about 1.3 ounces per square yard (44 g/m^2) and is flexible yet stiff enough to maintain the shape of the checkvalve fabricated (Fig. 12). Waterproof duct tape, common staples, and/or wooden lath strips are used to attach the netting to metal, slate, brick, wood, asphalt shingle, or other surfaces. Note that duct tape may stain or discolor painted/enameled surfaces if kept in contact for long periods of time.

Application of checkvalves follows the same two initial steps as traditional bat exclusion. Close interior openings, then close exterior openings except a few major exits. These latter openings will have been confirmed as important via bat watches, and it is here that checkvalves will be fitted during the daylight.

The basic design is to attach the netting around an exit hole except at the bottom where the bats will escape (see Frantz 1986, for details). The width and shape of checkvalves is highly variable so as to embrace the necessary exit point — a single hole, a series of holes, or a long slitlike opening (Fig. 13). Designs must be open enough not to impede the exiting bats. The top can be much larger than the bottom. It is probably best to restrict the bottom opening to no larger than about 1.6 x 1.6 feet (0.5 x 0.5 m). The length of a checkvalve, that is, the distance from the lowest enclosed point of egress to the bottom of the netting, should be about 3.3 feet (1 m).

The above specifications usually are sufficient to abort bats' reentry attempts. If netting is applied while young are still in the roost, the "evicted" mothers may be motivated to chew holes in the netting to reenter the roost. Applied at the correct time of year, however, netting will allow all bats to exit at dusk and thereafter deny them reentry.

Checkvalves should be kept in place for 3 to 5 days. It is best to verify (conduct a bat watch) that bats no longer exit at dusk before the checkvalves are dismantled and the holes are sealed permanently. As in any exclusion intervention, the excluded animals will go elsewhere. This shift may be to an alternative roost already in use such as a night roost, or one used in previous years.

Supplemental Materials and Methods. While specifications for Frantz' checkvalve have been

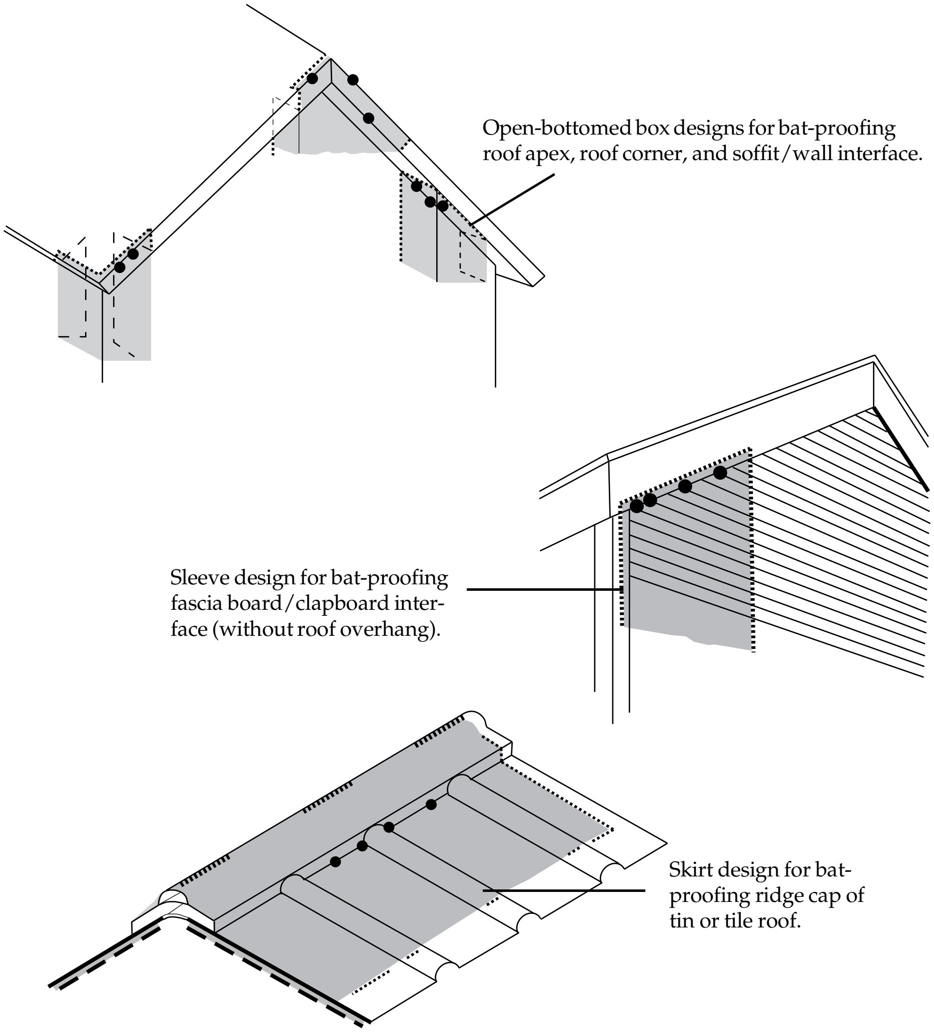

Fig. 13. Sample configurations for Frantz’ checkvalve (Key: [grey box] = birdnetting; .... = attaching to structure; • = exit/entry holes of bats).

provided, additional caulking, flashing, screening, and insulation materials often are needed. The combination of materials used will depend on the location, size, and number of openings, and the need for ventilation. Greenhall (1982) provides many details of bat-proofing methods and materials and is a practical guide. Weatherstripping, knitted wire mesh (Guard-All®, Stuf-fit®), waterproof duct tape, stainless steel wool, and wood lath may be used to block long, narrow openings. Caulk-ing compounds will seal cracks and crevices that develop in a house as it ages, and are best applied during dry periods when wood cracks are widest. Caulks that may be applied with a caulking gun (in gaps up to about 0.4 inch [1 cm] wide) include latex, butyl, and acrylic, which last about 5 years. Elastomeric caulks, such as silicone rubber, will last indefinitely, expand and contract, do not dry or crack, and tolerate temperature extremes. Oakum packs easily and firmly into small cracks. Other fillers include sponge rubber, glass fiber, knitted wire mesh, and quick-setting putty. Self-expanding polyurethane foam applied from pressurized containers can be used for openings larger than 3 inches (>7.5 cm). It must be applied with caution so as to not lift clapboards, shingles, and other surfaces. Exposed surfaces should be sealed with epoxy paint to prevent insect infestation and ultraviolet degradation.

Conventional draft sweeps (metal, rubber) and other weatherstripping supplies (felt, vinyl, metal) will seal the space between a door bottom and the threshold or around windows (Fig. 14). Remember to treat attic and basement doors whenever the gap exceeds 1/4 inch (0.6 cm). Flashing may be used to close gaps wherever joints occur; for example, where the roof meets a chimney. Materials commonly used include galvanized metal, copper, aluminum, and stainless steel. Self-adhesive stainless steel “tape” is also available. Insulation will provide some degree of barrier to bat movements. It is available in a number of forms and types including fiberglass, rock wool, urethane, vermiculite, polystyrene, and extruded polystyrene foam. Inorganic materials are fire and moisture resistant; the safest appear to be fiberglass and rock wool.

The mesh size of screening must be small enough to prevent access of bats and other species, where desired. Hardware cloth with 1/4-inch (0.6-cm) mesh will exclude bats and mice; screening with 16 meshes per inch (2.5 cm) will exclude most insects. Soffits (underside of overhanging eaves) usually have ventilators of various shapes and sizes. Regardless of type, the slots should not exceed 1/4 x 1 inch (0.6 cm x 2.5 cm) and should be covered inside with insect mesh. To prevent bats from entering chimney flues, completely enclose the flue discharge area with rust-resistant spark arresters or pest screens, secured to the top of the chimney. These should not be permanently attached (for example, with screws) in case they must be rapidly removed in the event of a chimney fire. Review fire codes before installing flue covers. Dampers should be kept closed except in the heating season.

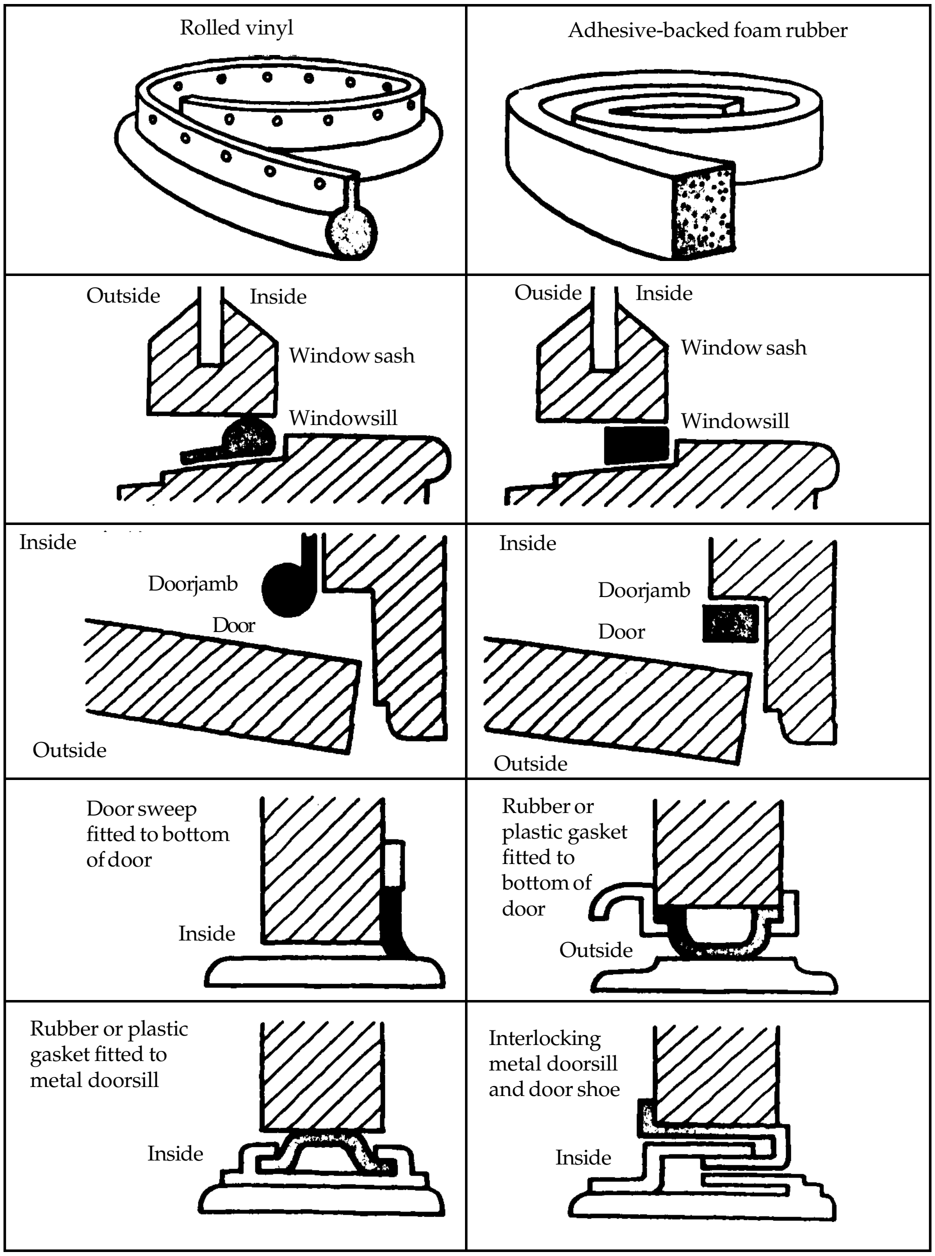

Fig. 14. Weatherstripping and door sweeps are very useful bat-proofing measures.

Fig. 15. Open ends of tile roofs may allow bat entry and provide roosting sites.

Roof Problems. Bats, particularly the Mexican free-tailed bat, often roost under Spanish or concrete tile roofing by entering the open ends at the lowermost row or where the tiles overlap (Fig. 15). Tight-fitting plugs are difficult to make due to the variation in opening sizes and thermal expansion and contraction. A solution was found by Constantine (1979) in which a layer of coarse fiberglass batting was laid under the tiles so that bats entering holes would contact the fiberglass and be repelled. A layer of knitted wire mesh would undoubtedly work well for this purpose (and would not hold moisture). Bats also may be excluded from the tiles if rain gutters are installed directly under the open ends. Gaps under corrugated and galvanized roofing may be closed with knitted wire mesh, self-expanding foam (avoid causing roofing to lift), or with fiberglass batting (may retain moisture).

Wall Problems. Fiberglass or rock wool insulation blown into wall spaces that are used by bats may be a deterrent, especially when it forms a physical barrier to passage. Such work must be done when bats are absent to avoid their entrapment.

Temporary Roosts. Bats will sometimes temporarily roost on porches and patios, in garages, and behind shutters, shingles, and roof gutters. Roosting behind shutters may also be long-term in duration. Actual control measures may not be necessary unless bat droppings become a problem or the risk of human contact is significant. Coarse fiberglass batting tacked to the surfaces where bats prefer to hang sometimes discourages them. A potentially useful intervention for the wall-ceiling interface is the application of a wide 45° molding strip to eliminate the 90° angle corner and force the bats to roost in a more exposed area.

Repellents

While many chemical aromatics and irritants have been proposed and tested for bat repellency, efficacy has been very limited thus far.

Naphthalene crystals and flakes are the only repellents registered by the US Environmental Protection Agency (EPA) for indoor bat control and are to be applied in attics or between walls. Sometimes the chemical may be placed in loose-mesh cloth bags and suspended from the rafters. About 2.5 pounds per 1,000 cubic feet (1.2 kg/30 m^3) is recommended to chronically repel bats as the chemical vaporizes. Dosages of 5 pounds per 1,000 cubic feet (2.4 kg/30 m^3) may dislodge bats in broad daylight. Bats will return, however, when the odor dissipates. The prolonged inhalation of naphthalene vapors may be hazardous to human health.

Illumination has been reported to be an effective repellent. Floodlights strung through an attic to illuminate all roosting sites may cause bats to leave. Large attics may require many 100-watt bulbs or 150-watt spotlights to be effective. Fluorescent bulbs may also be used. In some situations such lighting is difficult, costly, and may result in an electrical hazard. Where possible, the addition of windows to brighten an attic will help to reduce the desirability of the roost site and is not likely to introduce additional problems.

Air drafts have successfully repelled bats in areas where it is possible to open doors, windows, or create strong breezes by use of electric fans. Addition of wall and roof vents will enhance this effort, as well as lower roost temperature. These measures will increase the thermoregulatory burden on the bats, thus making the roost less desirable. In a similar fashion, colonies located in soffits, behind cornices, and other closed-in areas can be discouraged by opening these areas to eliminate dark recesses. Discourage bats from roosting behind shutters by removing the shutters completely or by adding small blocks at the corners to space them a few inches away from the wall.

Ultrasonic devices have been tested under natural conditions, both indoors and outdoors, to repel little brown and big brown bats either in the roost or as they fly toward an entrance hole (Frantz, unpublished data). The results have not been promising. Numerous ultrasonic devices have been removed from clients' homes because the bats remained in the roost after the devices were activated. Hurley and Fenton (1980) exposed little brown bats to ultrasound in seminatural roosts with virtually no effect. Largely because of this lack of known scientific efficacy for ultrasonic devices, the New York State Consumer Protection Board has cautioned against the use of such devices (NYSCPB 1988). Part of the concern is that such devices will provide consumers with a false sense of security and, thus, may prevent them from taking effective preventive actions.

Distress cries of bats recorded on tape and rebroadcast can be used to attract other bats to nets or traps, but they do not serve as an effective repellent. Little brown and big brown bats respond to their own distress cries but not to the cries of other species.

Contact repellents, such as sticky-type bird repellents and rodent glues, have been used successfully in situations where roost surfaces and bat accesses may be coated. Apply masking tape to the surface first if you desire to remove the repellent after treatment is finished. Replenish contact repellents occasionally, since dust accumulation causes them to lose their tackiness. Also, caution must be exercised so as to apply coatings that will be sticky, but will not entrap the bats.

Toxicants (not recommended)

No toxicants are registered for controlling bats. In 1987 the Centers for Disease Control, United States Department of Health and Human Services, voluntarily withdrew the last registration for DDT use against bats in the United States. Thus, DDT is no longer registered for any use in this country.

Although federally registered for rodents, chlorophacinone (RoZol) tracking powder, an anticoagulant, is not registered for bats. Furthermore, it can no longer be registered by individual states for restricted use under Section 24(c) of the Federal Insecticide, Fungicide, and Rodenticide Act D-18 (FIFRA). Lipha Tech, Inc. (the manufacturer of RoZol) has voluntarily cancelled its registration for "RoZol Tracking Powder for Control of Nuisance Bats" — effective December 16, 1991 (Fed. Reg., 1991).

Trapping

Kunz and Kurta (1988) reviewed an extensive variety of efficient methods for trapping bats from buildings and other roosting sites or foraging areas. For purposes of wildlife damage control, however, exclusion is less complicated to carry out, less time-consuming, more effective, and requires no handling of bats.

Other Methods

Sanitation and Cleanup. Once bats have been excluded, repelled, or have departed at the end of the summer, measures must be completed to make reinfestation less likely, and to eliminate odor and problematic bioaerosols. As a prelude to such work, it is sometimes useful to apply a pyrethrum-based, total-release aerosol insecticide to eliminate unwanted arthropods.

The safe handling and removal of bat guano has been discussed previously (see the histoplasmosis section in this chapter). In addition to the more bulky accumulations of excreta, there are often diffuse deposits of guano under/among insulation materials, caked urine and guano on roof beams, and splattered urine on windows. Such clean-up work during hot summer weather may be the least desirable activity of a management program, but it is necessary.

All caked, crystallized bat urine and droppings should be scraped and wire-brushed, as necessary, from all roof and attic beams. For this procedure, workers should take the same precautions as outlined for histoplasmosis-related work. Accumulated excreta and contaminated insulation should be sealed in plastic bags and removed for disposal. Remove all remaining droppings and debris with

Fig. 16. One of five bat houses constructed to provide an alternative roost for bats excluded from nearby structures.

a vacuum cleaner, preferably one that has a water filter to reduce the amount of dust that escapes from the cleaner's exhaust.

Where possible, wash with soap and water all surfaces contaminated with urine and guano. Allow the surfaces to dry, then disinfect them by misting or swabbing on a solution of 1 part household bleach and 20 parts tap water. Ventilate the roost site to allow odors and moisture to escape. Installation of tight-fitting window screens, roof and/or wall ventilators in attics will enhance this process. Remember, sanitation and cleanup accompanies bat-proofing and exclusion measures, it does not replace them.

Artificial Roosts. For more than 60 years, artificial bat roosts have been used in Europe. Only recently have they gained some popularity in the United States. Though the results are variable, it appears that artificial roosts, if properly constructed and located, can attract bats that are displaced or excluded from a structure. The Missouri Department of Conservation described a successful "bat refuge" that was quickly occupied by a displaced colony of little brown bats (LaVal and LaVal 1980). Bat houses of a similar design have been successfully used in Minnesota, New York, and elsewhere (see Fig. 16).

Development of an efficient method to relocate bats into alternative roosts after they have been excluded from buildings could be an important intervention in comprehensive bat management. Frantz (1989) found it helpful to "seed" newly constructed bat houses with several bats, a procedure that later resulted in full-scale colonization without further human interventions. Alternative roosts should be located away from human high-use areas. Thus, people can enjoy the benefits of bats without sharing their dwellings with them and with little risk of direct contact with them.

Economics of Damage and Control

Virtually all bats are of some economic importance; those north of Mexico are beneficial because of their insectivorous diet which eliminates many insect pests of humans. The accumulated bat droppings, called guano, is rich in nitrogen and is a good organic fertilizer. At one time, bat guano was commercially mined in the Southwest; but its importance has declined due to reduced bat populations and the development of inorganic fertilizers. Bat guano is still considered a valuable fertilizer resource in some parts of the world (such as Thailand and Mexico).

No figures are available to determine the extent of damage caused by nuisance bats or the cost for their control. The problem is widespread in this and other countries.

Costs for remedial services are highly variable, depending on the nature of the problem and who will do the work. For example, to fabricate a few Frantz' checkvalves on the "average" two-story house would probably require two workers about one-half day, mostly on stepladders, and less than $50 in materials. Much more time would be required to seal up all the other active and potential bat exit/entry holes. In addition, if a deteriorated roof, eaves, or other woodwork must be replaced, the costs can increase rapidly.

It is often difficult or expensive for the public to obtain the services of reliable, licensed pest control operators (PCOs). Many PCOs have limited knowledge of basic bat biology and are apprehensive to work with bats. They may want to avoid any liabilities should bat-human contact occur. Select a qualified professional service that concentrates on the exclusion of live bats from a structure rather than on use of lethal chemicals.

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Figures 2 through 4 from Barbour and Davis (1979).

Figure 5 adapted from Harvey (1986).

Figure 6 adapted from Tuttle (1988), except *Yuma myotis* and Keen's bat (from Barbour and Davis 1979).

Figure 7 adapted from Trimarchi and Frantz (1985).

Figure 8 by R. Suss.

Figures 12, 15, and 16 by S. C. Frantz.

Figures 9, 10, 11, and 14 from Greenhall (1982)

Figure 13 by S. C. Frantz

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