BATS IN HUMAN DWELLINGS: HEALTH CONCERNS AND MANAGEMENT

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INTRODUCTION

The natural roosts of insectivorous bats in the northeast US are typically caves, rock crevices, and hollow trees. A few species, primarily *Myotis lucifigus* (little brown bat) and *Eptesicus fuscus* (big brown bat), have readily adapted to living in the houses and other structures of humans. During the warmer months of April through October, commensal bats sometimes become a nuisance due to their colonial habits and resultant odors, noises, guano deposits, and associated aesthetic and economic damages. Bat ectoparasites and at least one fungal disease, histoplasmosis, are of some medical import and the observation of bats flying about a residence is frequently disturbing to the human occupants. The most important public health concern related to commensal bats is the potential for rabies infection and the complications associated with possible exposure to that disease. Although the probability of rabies infection in a bat is not great, the possibility greatly influences management decisions.

RABIES

GENERAL EPIDEMIOLOGY

The death from rabies in 1983 of a young girl in Michigan, several months after an apparent bat bite went untreated, dramatizes the importance of preventing direct human contact with bats, managing bat bites properly, and maintaining proper immunization of pets (Centers for Disease Control, 1983a). At the same time, the incidence of rabies in bats and the danger of transmission to terrestrial animals has often been exaggerated.

Rabies in bats is widespread on this continent. It has been reported from all of the contiguous US and from most provinces of Canada, and has been isolated from all of the 40 North American species of bats that have been adequately sampled (Constantine, 1979). The data from New York State are typical of the extent and distribution of the problem throughout the northeast (Trimarchi and Debbie, 1980). Bat rabies constitutes a major proportion of all reported rabid animals each year in New York (Table 1), and in several northeastern states bats are frequently the only animals reported infected with rabies virus (Centers for Disease Control, 1983b).

The number of confirmed rabid bats in New York has gradually increased during the last decade. However, the proportion of rabid bats among all those examined has not significantly changed during this period, suggesting greater numbers of animals submitted for examination due to recognition of the problem as an explanation for the "increase" (Table 2). The observed prevalence during this period, ranging from 2.6 to 4.3% with a mean of 3.6%, does not imply that this proportion of all bats is infected with rabies. The majority of animals submitted for testing are examined because they have had contact with humans or pets or are otherwise abnormal in their behavior. This suggests that, even among sick bats, only about 4% are ill due to rabies infection. Extensive sampling studies indicate an overall infection rate of only a fraction of 1% (Constantine, 1979). Finding one rabid bat in a colony does not imply that the remaining animals are also rabid. In fact, the likelihood of finding more than one additional infected bat in that population right away is small (Trimarchi and Debbie, 1977), although the probability of having additional sick bats in that population over the next several years is apparently greater than would occur in randomly selected colonies.

Of the two common house bats, the prevalence of rabies is greater in *E. fuscus*. Since 1977, 5.3% of *E. fuscus* examined in New York State were rabid, compared with a rate of 1.2% for *M. lucifugus*. Also, *E. fuscus* has accounted for 71% of all confirmed rabid bats since 1972 (Table 3). Though rarely encountered by humans because of their solitary, arboreal habits, three migratory species of bats found in New York State are occasionally found rabid. They are *Lasiurus borealis* (red bat), *L. cinereus* (hoary bat), and *Lasionycteris noctivagans* (silver-haired bat).

Bats are not asymptomatic carriers of rabies. After an incubation period of from two weeks to six months, they become ill with the disease that may last as long as 10 days (Bell, Moore and Raymond, 1969). During this clinical period, a rabid bat's behavior is generally not normal—they may be found active during the daytime or on the ground incapable of flying. Even less frequently, they may be involved in unprovoked attacks on people or pets (Trimarchi, Abelseth and Rudd, 1979). It is during this period of illness that the rabid bat may be capable of transmitting the disease by biting another mammal (Bell, 1959). The disease becomes progressively paralytic, and that bat dies as a result of the infection. The virus in the carcass of such animals is reported to remain infectious until decomposition is well advanced (Lewis and Thacker, 1974).

HUMAN EXPOSURE

There are several important public health problems resulting from bat rabies. The most significant is the

Table 1. Distribution of rabies among animal species in New York State (excluding New York City).

Species	Number rabid (% of total animals rabid per year)				
	1978	1979	1980	1981	1982
Bat	39 (63.0)	34 (70.8)	39 (97.5)	41 (48.0)	47 (39.2)
Fox	18 (29.0)	8 (16.7)	1 (2.5)	29 (34.0)	35 (29.2)
Skunk	0	2 (4.2)	0	3 (4.0)	21 (18.5)
Cat	2 (3.2)	0	0	2 (2.0)	1 (0.8)
Dog	0	1 (2.0)	0	3 (4.0)	2 (1.6)
Livestock	2 (3.2)	3 (6.3)	0	7 (8.0)	12 (10.1)
Coyote	1 (1.6)	0	0	0	0
Raccoon	0	0	0	0	1 (0.8)
TOTAL	62	48	40	85	119

Table 2. Bat rabies in New York State, 1973-1982.

Year	Number examined	Number rabid	Percent rabid
1973	411	17	4.1
1974	423	17	4.0
1975	670	25	3.7
1976	694	24	3.5
1977	811	31	3.8
1978	1088	39	3.6
1979	1318	34	2.6
1980	1106	39	3.5
1981	1057	41	3.9
1982	1110	47	4.3
TOTAL	8688	314	3.6

potential for transmission to humans. Since 1981 nearly 9% of all bats examined and 15% of those confirmed rabid in New York State were reported to have had contact with humans. A person is potentially exposed to rabies if bitten by a bat or if the saliva or nervous tissue of a bat comes in direct contact with an open wound or mucous membrane. When a bite occurs, the victim should immediately wash the wound thoroughly with soap and water, capture the bat without damaging the head, seek medical attention right away, and contact the local health department in order to have the bat examined for evidence of rabies. If the bat is confirmed rabid or cannot be tested for any reason, the patient must undergo rabies post-exposure vaccination. This currently consists of one dose of rabies immune globulin and a series of five injections of human diploid cell rabies vaccine (HDCV) administered in the arm over a period of one month (Centers for Disease Control, 1980). The treatment is considered safe, effective, and generally without side effects. It costs approximately $500 per patient.

PET EXPOSURE

The transmission of rabies from bats to terrestrial mammals is apparently a rare event, as evidenced by the numerous areas of the US where rabies is reported only in bats (Centers for Disease Control, 1983b). However, the potential of bats as a source of infection creates some problem related to companion animals. A person bitten by an unvaccinated dog or cat may require post-exposure vaccination, even in an area free of rabies in terrestrial mammals, because of the possibility of bat-to-pet transmitted rabies. In New York State, if a cat or dog does not have a current rabies vaccination and is in contact with a rabid bat, the animal

Table 3. Species of rabid bats in New York State 1973-1982 (excluding New York City).

Common name (*species*)	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	Total	Percent of all rabid bats for period
Big brown (*Eptesicus fuscus*)	8	12	16	18	18	32	28	31	32	32	223	71
Little brown (*Myotis lucifugus*)	2	1	2	2	3	5	4	5	9	4	37	12
Red (*Lasiurus borealis*)	0	1	1	2	3	1	0	0	1	6	15	5
Hoary (*Lasiurus cinereus*)	1	1	1	2	4	0	0	3	2	3	14	5
Silver-haired (*Lasionycteris noctivagans*)	0	0	0	0	1	0	0	0	0	0	1	0.5
Eastern pipistrelle (*Pipistrellus subflavus*)	0	1	0	0	0	0	0	0	0	0	1	0.5
Unidentified	6	1	5	0	2	1	2	0	0	2	19	6
TOTAL	17	17	25	24	31	39	34	39	40	47	310	

must be strictly isolated for four months or euthanized (NYSDH, 1983). This results in the confinement or destruction of many animals each year and could mostly be avoided by the timely rabies vaccination of companion animals, especially cats. Of the 2,030 bats submitted for rabies examination in New York State since 1981, 38% had reported contact with a cat while only 5% had contact with a dog. Urban pets, even those confined indoors, should be immunized since contact with bats frequently occurs in homes and apartments.

Efforts to control bat rabies emphasize educating the public (to avoid exposure to bats and how to respond when exposure occurs) and health professionals (to insure that materials are available for rabies diagnosis and proper management of bat bite cases). Attempts to actually reduce the prevalence of rabies in bats have been limited to elimination of remaining animals at roosts associated with a laboratory-confirmed rabid bat.

The potential exposure of the public to bat rabies may be reduced by removal of colonies and prevention of roost repopulation in structures that present a high likelihood of human contact with bats. High risk locations include institutions such as schools, hospitals, nursing homes, and prisons, as well as private residences where contact between the inhabitants and bats seems probable.

MANAGEMENT TECHNIQUES AND TOOLS

GENERAL

Each year the New York Department of Health receives hundreds of inquiries regarding bats from homeowners, commercial establishments, public health personnel, and institutions. Our primary services include rabies diagnosis; direct response to inquiries by telephone or in writing; providing literature regarding basic bat biology, behavior, and management; on-site investigations; and removal of colonies in which bats are found positive for rabies.

The typical case does not involve rabies and, because of the large volume of inquiries, a prioritization is necessary for determining potential risks, severity of the problem, and which cases to visit. For example, an urban structure inhabited by people and pets would generally have a higher priority than a rural, vacant barn. An indoor recurring infestation, especially in the living quarters, would receive more attention than an occasional outdoor observation of flying bats. Grounded bats are of particular concern since they could be ill (possibly rabid) and are accessible to inquisitive people and pets; however, it is common for these bats to be pre-volant young, especially if found in July and August. Such animals may indicate the location of a nearby colony, probably in the structure where found. The separation of inquiries regarding individual bats from those with active colony roosts is important because the latter involves an ongoing infestation for which management, if desired, is more complicated than the simple removal of an occasional interloper. Thus, the first step in handling an inquiry is to define the alleged problem, provide information to the client, and allay unreasonable fears.

INDIVIDUAL BATS

Where a problem consists of a single bat in a residence and no person or pet contact has occurred, we recommend clients to confine the bat to one room by closing the doors to other parts of the house. Then open exterior doors and/or windows to enable the bat to exit. Be patient, remain quiet, and observe to see that it exits. If the bat does not easily find its way out, wait for it to come to rest, cover it with a small can or similar container, slide a piece of cardboard under the can to trap the bat inside, take the trapped bat outdoors and release it. Note that our general guidelines always include: 1) do not handle bats directly; 2) wear gloves when capturing bats; 3) keep children and pets from contacting bats; and 4) insure that rabies vaccinations of pets are kept up-to-date.

COLONIAL BATS

Bat Watch

In order to confirm that bats are roosting in a structure, observe for bats flying in and out of the site and/or look for signs of infestation. A bat watch can be conducted by two people posted at opposite corners of a structure (it may be necessary to use more people to observe all sides of some buildings) to observe for flying bats for about one hour, beginning 30 minutes before dark. Such observations indicate points of egress, colony size, and, with some practice, it is possible to determine bat species. That is, compared to *E. fuscus*, *M. lucifugus* is noticeably smaller in size, has a more rapid wing beat, and its flight is characterized by more rapid turning and darting about. In New York State, bat watches are appropriate only during the period of late April through early October when commensal bats occupy human structures and forage outdoors nightly for insects.

Roost Location

If a bat watch cannot be conducted to confirm the presence of an infestation, an inspection of the premises for bats or bat signs is necessary to find specific roost locations. Even in the winter, when most bats have returned to hibernacula, some *E. fuscus* may be found overwintering in structures (Barbour and Davis, 1969). Bats roost in the most varied kinds of buildings and in literally every part from cellar to attic. Some types of buildings appear preferable (older houses, churches, barns) as do certain roost locations therein, especially areas with little disturbance, low illumination, little air circulation, and high temperatures (Greenhall, 1982; Kunz, 1982b; Ryberg, 1947). Often it is easy to locate bats, especially in warm weather in attics or lofts, where they may hang in tight clusters or side-by-side from the sloping roof lath, beams, ets. lath, beams, etc. However, bats have a unique ability to find crevices and cavities in buildings, and if disturbed may rapidly disappear into the angles between converging beams, in the void behind such beams or wallboards, and into mortise holes on the underside of beams. Numerous recesses are provided by most roof and wall construction which is generally layered with narrow spaces between. In our experience, *M. lucifugus* readily squeezes through spaces of 6.4 mm (1/4 in) between boards. Greenhall (1982) reports that *M. lucifugus* can enter openings 1.6 by 2.2 cm (5/8 x 7/8 in) and *E. fuscus* passes through holes 1.3 x 3.2 cm (1/2 x 1 1/4 in). If bats cannot be openly observed, their various signs usually make it possible to locate them.

Signs and Associated Problems

Bats nearly always reveal their presence by deposits of feces (guano) found beneath roosts and entrance holes. Fecal droppings tend to be elongate, firm, and of dark color; when dried, the consistency is porous and friable with many small, undigested pieces of chitin and wings from devoured insects. The relative size of droppings is a good indication of species. Bat droppings are easily distinguishable from those of mice which taper at both ends, are hard when dry, and are not easily crushed. Guano deposits from large numbers of bats may reach alarming proportions. In one small outbuilding recently studied, the owner commonly collects 18-38 l (5-10 gal) of guano per summer from a colony of only a few hundred *M. lucifugus*. Defecation and urination occur during flight as well as when the bat is roosting. Urine and feces excreted in flight often adheres to vertical walls within a roost area and to exterior walls beneath entrance holes. This results in a spattered appearance which can become an unsightly nuisance on a light-colored house.

The urine of bats is usually colorless or faintly yellowish and readily crystallizes at room temperature into pin-shaped crystals (Ryberg, 1947). 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 impregnated with urine crystals acquire a whitish powder-like coating. With large numbers of bats, thick and hard stalactites and sometimes stalagmites of crystallized bat urine are formed.

Although the fresh urine of individual bats is relatively odorless, the dried accumulated urine has a strong, unpleasant smell. This is especially noticeable during damp weather, probably due to the fact that crystallized urine is hygroscopic. Bat urine which does not quickly evaporate and becomes mixed with feces gives off an ammonia-like or strong musty smell. The odor of accumulated bat excrements may contribute to the identification of roost sites by bats each spring, can be annoying to a homeowner, and can also guide us in locating roosts. One can often smell an infestation from outdoors even before conducting an inspection of the premises.

A form of mild wood deterioration may occur when bats utilize a roost site over several years, particularly if the number of animals is great. As bat urine saturates the surfaces of wood beams, roof lath, etc. and crystallizes, the wood fibers expand and separate. When bats move over such surfaces, wood fibers are apparently pulled off singly and in clumps by the constant scratching of the sharp claws of the hind limbs and thumbs of the front limbs. Scratched-off wood particles may be found mixed with guano deposits beneath heavily used roosts; the deteriorating action may be exacerbated by roof leaks which further moisten the wood. This condition is seldom observed and it is not known if it significantly compromises structural integrity. A similar condition has been reported by Ryberg (1947) for bats roosting in tree cavities.

Bat entryways in walls, between bricks, etc. often have the appearance of being polished. That is, the surface around the opening has a sticky, fatty gloss, may contain a few adhering bat hairs, and is often yellowish-brown in color. The smooth gloss of these rub-marks is due to oils from pelage mixed with dust and dirt and other bodily secretions deposited as many animals pass repeatedly over the same surface. Openings marked in this way indicate their importance (i.e., heavy use) for bat entrance and exit from a building. They may be found in various locations where cracks often appear due to warping or shrinking timbers and boards (e.g., the gables, where the roof rests on the wall; the eaves between soffit moldings; between clapboards, especially where they meet wall moldings), at chimney flashings where a gap exists between chimney and the house wall, and at the ridge cap of a roof.

Bats produce a variety of ultrasonic and sonic vocalizations, depending on species, age, and activity. Particularly with large maternity colonies, the audible piping, whistling, trilling, buzzing, and hissing sounds of bats may be disturbing to people living in close proximity. Other sounds are made when a bat grooms (a drum-like roll) or crawls about (scratching, rustling, creaking) while in contact with an object that serves as a sounding board (e.g., roof lath, wallboard, tin roofing, etc.).

Associated with colonies of bats in buildings is a rich diversity of arthropods (fungivores, detritivores, predators, and bat ectoparasites) depending upon the number of bats, age and quantity of excreta deposits, and season (Bernath and Kunz, 1981). Some arthropods such as dermestid beetles undoubtedly contribute to the decomposition of guano and insect remnants, but may also become a pest of stored goods (e.g., woolens) and/or a nuisance within the living quarters. According to Wimsatt (1970), cockroaches are sometimes attracted to guano deposits and may subsequently invade other parts of a building. Bat ectoparasites (ticks, mites, fleas, and bugs) rarely attack humans and quickly die in the absence of bats (Greenhall, 1982). Bat bugs, *Cimex adjunuctus*, are sometimes found crawling on the surface of beams or around holes leading to otherwise overlooked, secluded recesses used by bats. Ectoparasites may become a nuisance following exclusion of large numbers of bats from a well-established colony roost. In such cases, fumigation with an insecticide may be necessary.

MANAGEMENT CONSIDERATIONS

Needs Assessment

Having confirmed that bats are inhabiting a structure, determine if they are doing any harm and if intervention is warranted. From the disease standpoint, we are primarily concerned if a bat has bitten or otherwise been in contact with a person or pet, or if there is a high potential for contact. Secondarily, consider the psychological impact of bats on the clients and the extent of problems related to guano deposits, stains, odors, and sounds. People often want to eliminate bats only because they've heard exaggerated claims of danger and are largely uninformed about basic bat biology and behavior (Kunz, 1982a; Peterson, 1964; Scarf, 1983; Tuttle and Kern, 1981). Before any attempt is made to remove or exclude bats, one must weigh the possible nuisance and risk against the benefit bats provide in consuming large numbers of insects. As a point of perspective, note that bats are partially protected in some states (Greenhall, 1982) and in some countries, such as Great Britain, it is illegal to kill or injure bats, to disturb them when roosting, or to block entrances to their roosts (BCI, 1983; NCC, 1982).

Timing

If it is desirable to eliminate bats from a structure, the developmental stage of the bats must first be considered. That is, interventions should not be initiated during July and early August when the young are prevolant because they may be trapped inside resulting in offensive odors then they die. Before the young are born in mid-June, or after they are able to fly in late August, it is easier to disturb colonies through various control actions and cause them to abandon a roost.

Sanitation

A necessary part of most bat management programs is the removal of guano deposits. That such accumulations may have an offensive odor and attract arthropod pests has already been discussed. In addition, people handling bat guano have some risk of histoplasmosis, a systemic fungal disease contracted through inhaling airborn spores mixed with guano dust. The etiologic agent *Histoplasma capsulatum* grows well in bird and bat droppings alone or in soil contaminated with such guano. Evidently, well-ventilated roosts do not favor transmission of *H. capsulatum* spores (Wimsatt, 1970), but the fungus can survive in guano found in hot, dry attics (Bartlett et al., 1982). The use of respirators and protective clothing is recommended when working in bat roosts, especially for sanitation activities which cause infectious spores to become airborne. Dry guano should be dampened with water before its removal. If vacuuming is desired, cleaners with a water filtration system should be used in order to prevent spores and guano dust from becoming airborne; vacuum cleaners with dry or bag filters are not recommended. Disinfection of guano with formalin may also be necessary prior to removal (Bartlett et al., 1969; Greenhall, 1982). Due to the hazardous qualities of formalin, extreme caution must be exercised in its application.

Commercial Services

It is often difficult or expensive for the public to obtain the services of commercial pest control operators (PCO's). We have found that many PCO's have a limited knowledge of basic bat biology and are apprehensive to work with bats or subject themselves to the low risk of possible exposure to rabies. In addition, they may want to avoid any liabilities should bat/human contact occur due to the real or imagined consequences of such work. Lawsuits involving considerable sums have resulted from human exposure to bats and toxicants following PCO's application of lethal measures to control bats (Greenhall, 1982). Certainly some PCO's are willing and capable of handling bat problems; our main recommendation in this regard would be to select a professional service that concentrates on exclusion of bats from a structure rather than killing them.

LETHAL MEASURES

Chemical

The management of commensal bat colonies is particularly complicated because techniques that kill have the potential to exacerbate health concerns. Bats may be driven into living quarters from attics or wall voids, and intoxicated animals may be dispersed into the community, become grounded and come in contact with people and pets (Barclay, Thomas and Fenton, 1980; Beck and Jackson, 1977; Hurley and Fenton, 1980; Kunz, Anthony and Rumage, 1977). Commensal bats are long lived, generally utilize a large geographic area, and it is not likely that a comparable rate of contact would occur as a result of normal mortality. The inherent risk of rabies and concomitant post-exposure treatment, whether rabies is confirmed or not, make such results unacceptable.

In recent times, DDT and chlorophacinone have been most widely used as bat toxicants. DDT wettable powder is the only toxic material registered with EPA for bat control, its use requires special approval from the Centers for Disease Control (US Dept. HHS, Atlanta, GA), and it can be used only indoors where a rabies health hazard has been demonstrated (Greenhall, 1982). DDT is not particularly effective since bats continue to return to treated roost sites (Barclay, Thomas and Fenton, 1980; Kunz, Anthony and Rumage, 1977). Additionally, residues of DDT and other organochlorine insecticides are toxic to commensal bats and may continue their effect for several years following application (Clark and Krynitsky, 1983; Clark, Kunz and Kaiser, 1978; Kunz, Anthony and Rumage, 1977). Because the long-range effect of insecticide application can be quite deleterious to bats and unnecessarily contaminates the environment, its use is ill-advised.

The anticoagulant rodenticide chlorophacinone, in a tracking powder formulation, has been registered by numerous individual states for restricted bat control under Section 24(c) "Special Local Needs" of the Federal Insecticide, Fungicide, and Rodenticide Act (FIFRA). Some authors report that chlorophacinone is ineffective on bats and dangerous to people (Constantine, 1979; Tuttle and Kern, 1981), and others report it to be efficacious in controlling colonies of *E. fuscus* (Corrigan and Bennett, 1982). While the judicious application of a slow-acting anticoagulant for bat control may not in itself constitute a health hazard (Hayes, 1982), the use of any "baticide" must be seriously questioned because of the adverse consequences discussed earlier.

For emergency situations when other measures are impractical, the issue of sickly or dying bats can be circumvented by tarping and fumigating a building. Various fumigants would kill bats rapidly, but none are specifically registered with EPA for bat control (Jacobs, in press) and their use is highly specialized, expensive, and restricted to certified applicators.

With application of any lethal measure, dead bats will need to be removed from a structure to prevent offensive odors—a task that may prove difficult since bats may die in inaccessible areas. Killing bats at the roost will not prevent site repopulation and such actions may have a long-term adverse effect on bat populations, the ecological significance of which is difficult to estimate. In addition, interrelationships between the incidence of rabies virus and naturally occurring rabies antibodies, stress, accumulated pesticides, and age structure in bat populations have not been adequately evaluated. Consequently, the application of toxicants for managing bats is largely contraindicated.

Nonchemical

People have devised numerous nonchemical methods for killing bats. We have recorded various measures ranging from hitting bats with a tennis racket, rubber mallet, or machete, to shooting them with a pellet gun, pistol, or shotgun. Unfortunately, some PCO's as well as uninformed homeowners have resorted to using such excessive, unwarranted, and ineffective practices.

REPELLENTS

Chemical

Numerous chemical aromatics and irritants have been proposed as repellents for application to roosts of commensal bats including formalin, oil of mustard, paradichlorobenzene, naphthalene, wood preservatives, and insecticides (Constantine, 1970 and 1979; Greenhall, 1982; Mampe, 1982; Sterner, Shumake, Gaddis, Ladd and Peterson, 1980). Naphthalene, crystals or flakes, is the only chemical registered by EPA for bat repellency and is restricted to indoor use. The recommended application rate is 2.3 kg (5 lb) per 60 m^3 (2,000 ft^3) for a chronic preventive repelling effect. Increasing the application to 4.5 kg (10 lb) is reported to "flush" bats from a structure (Greenhall, 1982). Note that naphthalene should not be applied in human living quarters per se because prolonged exposure to the vapors may be hazardous (Sittig, 1981). To be most effective, naphthalene should be well-distributed over the infested area including wall spaces. It can also be hung in mesh bags near bat roosts and entryways. Constantine (1979), Sterner et al. (1980), and a number of our clients report highly variable results with naphthalene. In our opinion, additional studies are warranted regarding the efficacy of naphthalene as a bat repellent and the effects of its chronic low level exposure on humans.

We have observed that some professional PCO's and homeowners continue to use organochlorine (e.g., chlordane and dieldrin) and organophosphorus (e.g., chlorpyrifos and dichlorvos) insecticides to flush bats from buildings. These exemplary compounds have essentially the same drawbacks listed earlier for lethal chemicals: their repellent effects are temporary, they may well kill bats as they have FIFRA toxicant classifications of Category I and II, some may not be used indoors, and they are illegal to use for bat control. That is, these compounds are not registered for bat control and such applications constitute pesticide misuse. Similarly, the label restrictions and health hazards of PCP wood preservatives preclude their use as bat repellents (Frantz, 1983). Pyrethrins (botanical insecticide, toxicity Category III) and synthetic pyrethroids in various synergized formulations (e.g., with piperonyl butoxide and/or silica aerogel) have been popularly discussed as bat repellents. Since these compounds have a low mammalian toxicity and reportedly flush small rodents from secluded harborages (Frishman, personal communication), they may deserve more attention as candidate bat repellents.

More studies are needed of bat repellent compounds, not only as flushing agents but as chronic or preventive repellents. The primary limitations of most nonlethal chemical repellents are that they are highly volatile and must be used in enclosed spaces in order to achieve effective concentrations, they must be reapplied regularly since reinfestation is not prevented as the concentration dissipates, they may inadvertently drive bats into living quarters, and their vapors may annoy or harm people. Properly used (after bats have emerged for evening foraging—early or late in the season when all animals are volant) a repellent with a minimum of a few days' effect may allow time for more permanent measures to be taken. Ideally, the single application of a repellent should prevent reinfestation for a few months, roughly the time period of the "bat season."

Nonchemical

Glues A broad range of non-chemical repellents have been used against bats with varying degrees of success (Barclay, Thomas and Fenton, 1980). Sticky, resinous materials such as rodent or bird glues can be brushed or sprayed in a thin layer on roosting surfaces and around entrance holes. Contact with these substances can discourage bats from utilizing treated surfaces.

Frequent reapplications may be necessary because glues lose their adhesiveness over time due to accumulations of particulate matter, temperature fluctuations, and desiccation. It is also reported that bats learn to avoid glue applications (Greenhall, 1982). Note that repellent-glue applications for bats should not be confused with the more adhesive applications used for insects and rodents as they might ensnare bats and that is not the objective.

Ultrasound Ultrasonic devices designed for rodent repellency have been reported to likewise repel bats. Theoretically, these devices interfere with the bats' navigation or otherwise disturbs them (Greenhall, 1982). However, the most effective combination of decibel/frequency and time of application have not been reported. Adult and subadult *M. lucifugus* have been exposed continuously to ultrasonic devices for periods of 24 hours in semi-natural roosts (Hurley and Fenton, 1980) and for one week in natural roosts (Frantz, unpublished data) with virtually no effect. While these results are not encouraging, additional work is planned with devices of other decible/frequency characteristics to determine if bats can be prevented from re-occupying a roost in March/April or can be flushed from a structure in August/September.

Some of the main difficulties with such instruments are that ultrasound ($>$20kHz) does not deflect around solid objects and its intensity (dB level) rapidly attenuates over distance. The complexity of most bat roosts in buildings, especially attics, probably offers infinite possibilities for bats to rest in "sound shadows." Hurley and Fenton (1980) report that it is not surprising that ultrasound does not repel bats that echolocate, given the intensity and frequency characteristics of their own vocalizations. They also point out that bats are attracted to the sounds of other bats, making the acoustic approach an unlikely alternative to measures such as lighting and exclusion. There is some potential for ultrasonic devices to adversely affect humans; e.g., annoyance, disorientation, headache, and short-term loss of auditory sensitivity (Knight, 1968; Parrack, 1966). However, damage potential depends not only on decibel level but on duration. This fact coupled with ultrasound's rapid attenuation over distance and straight path of travel should greatly reduce the probability of human exposure for sufficient time to cause injury.

Light Illumination is a clean and relatively safe method for repelling bats, assuming electrical wiring is adequate. It is obvious to anyone who has worked with bats in summer roosts that they are particularly sensitive to bright lights, and often move into the woodwork if illuminated for more than several seconds. Laidlow and Fenton (1971) have shown that floodlighting an attic with several spotlights (100-150 W) to illuminate all roosting areas can cause bats to desert a structure and move elsewhere. Perhaps the addition of windows to a dark space would have a similar effect.

HABITAT (ROOST) MODIFICATION

Habitat modifications involve some physical change in the bats' roost site that make it less desirable. Such modifications function as physical repellents and can be best applied in April before bats have returned or are first returning from hibernacula.

Temperature

As noted earlier, commensal bats have a definite preference for closed-in, dark areas with high ambient temperatures. Opening up such areas by adding wall and roof vents and/or ventilation fans creates drafts and reduces the ambient temperature. This increased the thermoregulatory burden on the bat, thus making the roost undesirable.

Insulation

Installing insulation can also lower the roost temperature and further deter bat occupation. In addition, blown-in cellulose or fiberglass insulation will effectively fill potential roost niches between walls, floor joists, etc. Constantine (1979) reported that contact with fiberglass may repel bats. Though often functioning in the same manner as blown-in materials, blanket-type insulation sometimes provides a new roosting niche when a gap is left between roof and insulation. If these blankets are faced with foil or heavy paper and are firmly secured to the roof beams, bats may not have access to the attic interior even if they are currently roosting on the exterior of the insulation and are utilizing points of egress through the roofing material, ridge cap, or chimney flashing. We have also found E. fuscus roosting under blanket insulation between the attic floor joists.

Miscellaneous

Colonies located in soffits, behind cornices, and other closed-in areas can be discouraged by opening these areas to eliminate dark recesses. Bats roosting behind shutters can be discouraged by removing the shutters or by adding small blocks at the corners to space them several centimeters away from the wall.

EXCLUSION (DENIAL OF RE-ENTRY: BAT PROOFING)

General

Authorities agree that the most satisfactory and permanent method of managing nuisance commensal bats is to exclude them from the structure (Barclay, Thomas, and Fenton, 1980; Constantine, 1979; Greenhall, 1982; Wimsatt, 1970). A colony of bats usually has only a few major points of egress. It should be pointed out, however, that when primary openings are covered or closed, bats will often utilize others. Hence, it is important to keep in mind that all gaps of 0.6-1.0 cm (1/4-3/8 in) and larger, depending on width, should be sealed.

Timing

Although mentioned before, the importance of timing cannot be overemphasized when discussing exclusion methods. Such intervention should not be conducted during July and early August when pre-volant young could be trapped inside. To exclude bats from an occupied roost, there are four necessary steps: 1) identify and close openings through which bats might gain access to human living quarters; 2) on one day, close most points of egress, leaving only a few major openings; 3) at night after the bats have departed to feed, temporarily close the remaining openings; and 4) check interior for additional bats and, if any remain, the openings should be unplugged early the next evening allowing them to escape prior to permanent sealing of the last hole. One-way excluder devices have been developed and may greatly facilitate the bat proofing process (Anonymous, 1983; Constantine, 1982). Returning bats may cluster or founder outside the sealed openings, but this behavior typically subsides within a day or two and the bats move elsewhere. Exclusion can probably be most efficiently applied during the winter months after all *M. lucifugus* and most *E. fuscus* have departed to hibernacula.

Materials

General materials for bat proofing include various caulking compounds, foam sealants (aerosol), oakum, weatherstripping materials, hardward cloth, and insulation. It is important to use relatively durable materials that can withstand the deleterious action of weather as well as bat activity. Although bats do not gnaw their way through building materials, they are capable of enlarging openings (Ryberg, 1947) and will push loose blockages such as fiberglass insulation out of a major entry hole.

One promising new material is polypropylene bird netting. It is black in color, strong, weather resistant, ultraviolet stabilized, and available in two grades: structural (with a diagonal hole opening of 1.6 cm [5/8 in]) and standard (2.4 cm [15/16 in]). Either grade is available in pieces as wide as 4.3 m (14 ft) by more than 1,000 m (1,094 yd) long. Since bird net is so lightweight, it is very easy to handle whether draping an entire building, the area around chimney flashing, or attaching to the underside of roof beams. Although our experience is limited to one product (Conwed® Birdnet), the low cost of materials and application should make bird netting particularly useful for bat proofing areas that would otherwise be too difficult or expensive. Corrigan and Bennett (1982) and Lann (personal communication) have also reported using bird netting for bat exclusion.

Application Sites

Any combination of the above materials should be used to exclude bats from structures. The particular material used will depend on the location, size, and number of openings, and the need for ventilation. House Bat Management (Greenhall, 1982) provides many details of bat proofing methods and materials and is a practical guide. Areas of a building most likely to need attention include roof, eaves, soffits, apex of the gable, and siding. In recent field visits in New York State, the following were particularly important: cracks between molding strips of the gable, soffits, and eaves; loose ridge cap, tin roofing, slate shingles, and chimney flashings; unscreened attic and roof vents; gap between exterior chimney and building; cracks around window frames and between clapboards; and unglazed, unscreened windows. Several cases were reported where bats entered opened doors or windows.

Occasionally bats enter a building via the chimney, particularly those leading to interior fireplaces. When this is a recurring problem, the flue opening can be covered with a rust-resistent spark arrester (hardware cloth basket with minimum mesh size of approximately 1.3 cm [1/2 in]) or other chimney cap. However, coverings should not adversely affect the draft (National Fire Protection Code, Section 211, Part 2.5) or cause creosote to accumulate that might result in a chimney fire. Because of fire hazard, any cover should be easily removable. In fact, it would be best to use a cover only during April through October when commensal bats might be a problem and when a fireplace is used infrequently.

CONCLUSIONS

The bulk of data regarding bat rabies indicate that most of these animals are healthy. However, because the small proportion of bats that are infected with rabies are widespread throughout North America, there is a potential health risk that makes public education and proper handling of bat contacts essential. This also significantly impacts on acceptable techniques for managing commensal bat populations. The number of bats considered to be a problem may vary from a single animal that accidentally enters a building to many hundreds that form a nursery colony in an attic or other indoor roost. Removal of individual stray bats is a relatively simple process, but colonies are more difficult to manage and require a thorough knowledge of roost locations and entry points. When circumstances require the elimination of bats from a structure, limitations of current technology and the need to minimize the risk of human contact make exclusion the most efficient strategy with long-term effect. The public health importance of this subject underscores the need for additional research and development of bat management techniques.

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