University of Nebraska - Lincoln
DigitalCommons@University of Nebraska - Lincoln

Proceedings of the Twelfth Vertebrate Pest Conference (1986)

Vertebrate Pest Conference Proceedings collection

March 1986

BATPROOFING STRUCTURES WITH BIRDNETTING CHECKVALVES

Stephen C. Frantz
Rodent and Bat Specialist, Wadsworth Center for Laboratories and Research, New York State Department of Health, Albany, New York

Follow this and additional works at: http://digitalcommons.unl.edu/vpc12

Part of the Environmental Health and Protection Commons

Frantz, Stephen C., "BATPROOFING STRUCTURES WITH BIRDNETTING CHECKVALVES" (1986). *Proceedings of the Twelfth Vertebrate Pest Conference (1986)*. 24.
http://digitalcommons.unl.edu/vpc12/24

This Article is brought to you for free and open access by the Vertebrate Pest Conference Proceedings collection at DigitalCommons@University of Nebraska - Lincoln. It has been accepted for inclusion in Proceedings of the Twelfth Vertebrate Pest Conference (1986) by an authorized administrator of DigitalCommons@University of Nebraska - Lincoln.

BATPROOFING STRUCTURES WITH BIRDNETTING CHECKVALVES

STEPHEN C. FRANTZ, Rodent and Bat Specialist, Wadsworth Center for Laboratories and Research, New York State Department of Health, Albany, New York 12201.

ABSTRACT: Denial of re-entry (batproofing) through structural modification is widely accepted as the most effective and ecologically sound method for eliminating commensal bats from structures. Such methods are clearly superior to lethal measures which have only questionable efficacy and may exacerbate bat/human interactions. However, since bats are able to enter small and obscure openings, conventional batproofing of all such openings is often not practical or economical. Further since this work must usually be done after bats have already begun roosting in a structure, the difficulty of high ladder work at night to seal exit holes can be discouraging to homeowners as well as to pest control operators. A few exclusion devices have been developed previously, but are not readily adaptable to the frequent situation where bats are using diffuse, large, and/or widely distributed exit holes. Polypropylene birdnetting has been field-tested over two seasons as a batproofing tool against little brown bats (Myotis lucifugus) and big brown bats (Eptesicus fuscus). In all cases the work was completed either before young were born or after they were able to fly. The netting is fitted as a checkvalve which allows bats to escape from a structure but prevents their re-entry; thus, the netting can be conveniently applied during daylight hours. At dusk, bats easily find their way out, do not become entangled, and are not driven indoors into the living quarters. At dawn, bats return in their typical swarming behavior, repeatedly land on the net, but are unable to find their way around or under it. Several checkvalves designs have been adapted to cover different patterns of exit holes associated with various architectural details. Specific application techniques with birdnetting checkvalves and responses of the bats are discussed in reference to overall bat management programs.

INTRODUCTION

General

Incidents of single bats occasionally entering human dwellings and associated buildings call for little more "control" effort than assisting the bat to exit, where no person or pet contact has occurred (Fenton 1983, Frantz and Trimarchi 1984, Greenhall 1982). However, despite their biological uniqueness and ecological significance in insect control, it frequently becomes desirable to exclude bats from buildings. This is especially true where maternity colonies have become established in homes with small children and pets, and in other situations where the risk of bat/human contact is high--including schools, hospitals and prisons, or the risk of contamination is unacceptable--as in food stores.

Among the 40 species of bats in the United States, only a few are likely to become a significant nuisance in structure. Problems stem largely from bats' colonial habits in which aggregates of several hundred are not uncommon (Barbour and Davis 1969, Hill and Smith 1984), though more than 9,500 have been reported (Morano 1964) in one building. Probably the most common "house bats" are: Myotis lucifugus (LeConte), little brown bat; Eptesicus fuscus (Palisot de Beauvois), big brown bat; and Tadarida brasiliensis (I. Geof. St.-Hilaire), Mexican free-tailed bait (Barbour and Davis 1969, Constantine 1979, Greenhall 1982). In addition, Myotis yumanensis (H. Allen), Yuma myotis, may occur in large numbers in the West and Antrozous pallidus (LeConte) is occasionally troublesome in the Southwest. E. fuscus frequently is found in the same structure with—though usually segregated from--other bats, such as Tadarida, Antrozous, and M. yumanensis in the West, and M. lucifugus in the East (Barbour and Davis 1969, Krutzsch 1946, Schowalter et al. 1979). Bat species of commensal importance in various areas of the world are discussed in Hill and Smith (1984), Kunz (1982) and Wimsatt (1970).

In North America, E. fuscus, M. lucifugus and M. yumanensis have so completely adapted to human structures during maternity periods that there are few records from natural roosts (Barbour and Davis 1969). The current presentation will focus on the widely distributed E. fuscus and M. lucifugus. However, it is important to correctly identify a nuisance species since some (e.g., the Indiana bat (Myotis sodalis Miller and Allen) and Gray bat (Myotis grisescens (Howell)) are protected by law and irresponsible control actions may have significant legal and ecological consequences (Lera and Fortune 1980). Useful species keys and descriptions are provided in Barbour and Davis (1969) and Greenhall (1982). Species identification may be difficult and further assistance may be available from the cooperative extension, wildlife or the biology departments of your state university or from the state environmental conservation or health department.

Definition of Problem

It is the maternity colonies of commensal bats in human dwellings which most commonly become a nuisance due to the resultant noises and vocalizations, guano and urine deposits, stains on walls and windows, odor (mostly of fermenting urine and guano mixtures), metal corrosion or other economic and aesthetic depredations, including unwarranted cultural phobias, e.g., "bats get in your hair." There is also the real risk of contracting rabies via a bat bite or nonbite exposure via bat nervous tissue or saliva in direct contact with human mucous membrane or a wound. Further, there are unpleasant consequences associated with even having been in contact with a confirmed rabid bat (or a bat that escapes after human or pet contact) which requires postexposure vaccination for humans and for dogs or cats

1986, Proceedings Twelfth Vertebrate Pest Conference
(T.P. Salmon, Ed.). Printed at Univ. of California, Davis, Calif.

without current rabies vaccinations, several months of strict isolation, or euthanasia. The concomitant emotional trauma associated with such events can be considerable.

MANAGEMENT

Exclusion (denial of re-entry and batproofing) is considered by virtually all authorities to be the most satisfactory and permanent intervention for managing commensal bat infestations (Barclay et al. 1980, Constantine 1979, Corrigan 1984a, Fenton 1983, Frantz and Trimarchi 1984, Greenhall 1982, Hill and Smith 1984, Marsh and Howard 1977, Wimsatt 1970). Bats points of egress vary from structure to structure, but commonly involve the roof, eave, soffit, apex of the gable, siding, chimney and attic or roof vent (Figure 1). The choice of openings probably depends on a number of factors, including proximity to suitable roosting niches within the structure, prevailing winds, and population density. Since closure of any primary entry point may result in bats utilizing other secondary openings, any gap of approximately 0.6 x 3.8 cm (1/4 x 1 1/2 in) must be considered a potential entry and should be closed. Identification of points of egress can be accomplished by conducting a "bat watch" at dusk (when bats currently roost in a structure) or by locating signs of bats (when they are not currently using a roost site) (Barbour and Davis 1969, Fenton 1983, Frantz and Trimarchi 1984, Greenhall 1982). Inspections for air leaks in attics and around door and window frames may further identify active or potential bat entries especially when only small numbers of bats are involved.

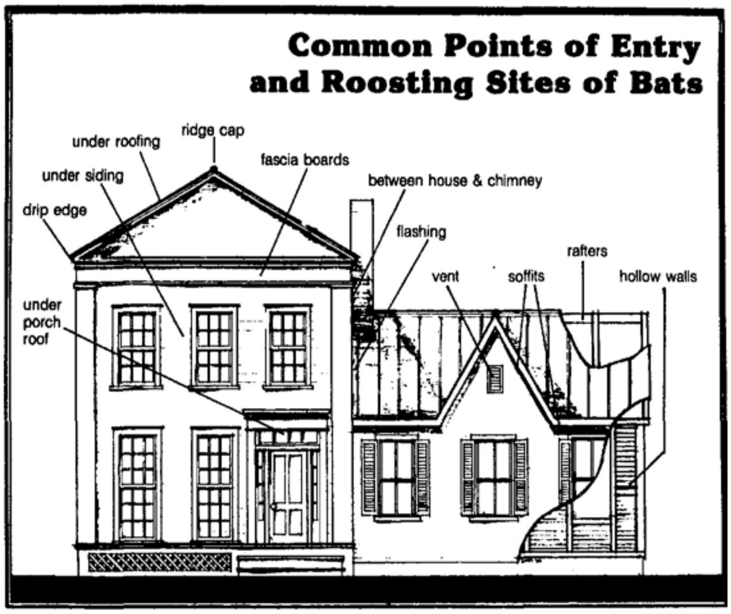

Figure 1. Common points of entry and roosting sites of bats in buildings (adapted from Trimarchi and Frantz, 1985).

When bats are not using a roost site, known and potential openings can be closed permanently with various light building materials (e.g., caulking compounds, cement, oakum, lath, sheetmetal, hardware cloth, window screen, etc.); bats do not chew or gnaw their way through such materials. In much of North America, there are several months each year between the fall/winter onset of hibernation and the spring formation of maternity colonies when most bats are absent from buildings and batproofing can be completed (Table 1). The timing of hibernation and return to summer roosts varies with latitude as well as with local weather conditions (Fenton 1983, Schowalter 1980); consultation with university or government authorities would provide useful information for a particular geographic area.

Bats hibernating in buildings, such as *E. fuscus* in North America (Constantine 1982, Fenton 1983, Schowalter and Gunson 1979, Whelden 1941), are a special problem. They may arouse out of hiberation in response to the onset of cold weather or other reasons and set out in search of water or a new roosting niche. Homeowners may then encounter the wayward bat flying about the living quarters, hanging on window curtains or drowned in a toilet bowl where it had been searching for water. In some areas, *E. fuscus* regularly become active when outdoor temperatures climb above the freezing point and will leave their hibernation site to fly about outside. Managing these bats is difficult because their numbers are small and the encounters occur at erratic intervals. Locating their access holes may not be feasible, but it is usually possible to seal off the attic and basement areas from the main living quarters. A good beginning effort should be focused on sealing gaps around doors leading to basement and attic, wall and ceiling electrical fixtures, ceiling moldings, baseboards, and any obvious cracks or holes leading into structural voids connected with the attic and basement. It may also be possible to close the spaces at the junction of the attic floor and basement ceiling which lead into the wall void.

Table 1. Biological events, for Myotis lucifugus and Eptesicus fuscus, of significance in timing bat management procedures.

Source	Study location	Colony formation	Parturition	Young Volant/ weaned	Hibernation begins
MYOTIS LUCIFUGUS					
Dymond, 1936	Ontario	--	June-mid July	--	--
Cagle & Cockrum, 1943	IL	1 Apr-mid May	17 May-12 July	mid June	Nov
Davis & Hitchcock, 1965	VT	22 Apr-mid May	7 June-10 July	mid July	Sept-Oct
Barbour & Davis, 1969	MA	mid May	--	--	--
Barbour & Davis, 1969	WY	--	July	--	--
Barbour & Davis, 1969	KY	--	21 May-21 June	--	--
Schowalter, Gunson, & Harder, 1979	Alberta	late Apr-mid May	mid June-mid July	late July	late Sept
Anthony, Stack & Kunz, 1981	NH	early May	--	late July	--
Fenton, 1983	Ontario	Apr	mid June	late July	late Aug-early Sept
EPTESICUS FUSCUS					
Whelden, 1941	NH	--	--	--	late Nov
Krutzsch, 1946	CA	--	late May-early June	--	Oct
Christian, 1956	MD	Apr	mid May-3rd wk June	last wk June-1st wk July	late Oct
Phillips, 1966	KS	Apr	--	--	Oct
Phillips, 1966	PA	--	--	--	Nov-Dec
Barbour & Davis, 1969	MD	--	1 June	--	--
Barbour & Davis, 1969	KY	mid May	last wk May-1st wk June	early July	Nov-Dec
Schowalter & Gunson, 1979	Alberta	early Apr-mid May	5 June-12 July	--	--

Unless it is totally unavoidable, exclusion measures should not be attempted from the time of parturition until the young are volant. Efforts otherwise are likely to trap young that cannot fly which will die and decay in the roost and may result in prevolent young or some adults (in attempts to escape) finding their way into the living quarters with concomitant risks of contact with people and their pets. The time period to avoid ranges from late May to late July (Table 1) depending largely on latitude. Again, consultation with local bat authorities will help one in timing management efforts so as to not unnecessarily destroy these valuable animals.

Thus, we have two time periods remaining: from when bats form maternity colonies until young are born; and from when young are volant and weaned (at which point maternity colonies begin to disintegrate) until they enter hibernation or migrate. Apparently, it is during the latter period that bats' presence is most obvious to homeowners. Fenton (1983) reports that in eastern Canada, most requests for bat control and submission of bats for rabies diagnosis coincides with swarming and mating periods, that is, just after young are weaned (which probably falls in late July and August). In New York State--for the period April to October (comprising >3200 requests in the past 3 years)--the Rabies Laboratory received about 20% of all similar requests in July and another 40% in August. As in eastern Canada, most occurred in the swarming/mating period with some overlap of the period when newly volant young are learning to navigate, having flight mishaps, and end up grounded or otherwise obvious to homeowners.

It is during these particular periods when denial of re-entry becomes the preferred mode of batproofing. Bats are in the roost site (e.g., an attic) throughout the daylight hours during which time control interventions would be wasteful, induce unnecessary stress and frenzied behavior in bats, and be likely to increase bat encounters with people and pets. However, by waiting until dusk, the bats will depart on their own to feed on insects throughout much of the night, interspersed with spells of roosting at this same site or others. M. lucifugus typically apportions the time between dusk and dawn into two foraging period separated by an interval of night roosting (Anthony et al. 1981). The departure at dusk is highly synchronous and the initial flight period lasts 1.5 to 3 hours. Departure for the second feeding period is asynchronous, but virtually all return at dawn. Conditions that may influence the time and duration of foraging flights and night roosting include: temporal aspects of (insect) prey activity, abundance of prey, predator activity, and energetic constraints. Terminally pregnant females often return early to maternity roosts at night (Kunz 1982), a factor to consider if batproofing work encroaches closer to the time of parturition; lactating females and newly volant young may also return early.

Traditional Batproofing

Traditionally, the time during the initial foraging flights is when batproofing measures have been applied, usually requiring a minimum of a few different days of effort (block minor holes, allow bats to adapt to fewer points of egress, block more holes, etc., until the structure is batproofed) (Corrigan 1984a, b; Fenton 1983; Frantz and Trimarchi 1984; Greenhall 1982; Hill and Smith 1984). Such work should be completed at least a few weeks prior to parturition or after young are volant in order to avoid excessively stressing animals during these sensitive developmental periods (Tuttle and Stevenson 1982). While traditional denial of re-entry methods is effective, a major drawback is the difficulty of high ladder work after dark to seal the last exit hole(s), a time period when bats flying about may also contribute to health and safety risks for the person on the ladder.

Bat Excluders

The difficulty of night work was overcome by Constantine's (1982) one-way, valvelike devices. His "combination tube" is composed of a semirigid plastic (butyrate) tube (attached over the bat entrance hole; 24 cm long x 4.9 cm dia.) plus a collapsible polyethylene tube (attached over the distal end of the butyrate tube); the latter tube functions as a valve in that it collapses shut when evicted bats try to re-enter. Constantine stated that, "uncommonly, bat entryway characteristics will permit using a simpler device, the collapsible slot guard", a laterally compressed polythene sleeve attached over an entryhole to form a chute about 20 cm long x 2.5 cm deep x 30 cm or more wide. More recently, a commercial device called the "EX-100 Hanks Bat Excluder" appeared on the market (Anon. 1983). It is sold in a kit of five excluders and two pieces (~ 30 cm x 90 cm each) of nylon window screen. An excluder consists of: a wooden plate (9 cm x 9 cm x 2 cm thick) with a 3 cm diameter hole through the middle; and a transparent plastic flappervalve which leads into a semirigid plastic mesh cone (6 cm dia. at base/over hole in wood; 11 cm long; 2 1/2 cm dia. at the exit opening). In use, the wood plate is mounted on a piece of window screen of sufficient size to cover the entryway and the screen is then attached to the building (Hanks undated).

The devices of Constantine and Hanks involve a one-way valve feature, can be readily installed during daylight hours, and properly applied will undoubtedly exclude bats from relatively small, discrete openings on a structure. These devices are designed to be used on the last few points of egress and excellent instructions are available for installing them. However, such devices are not readily adaptable to situations with large, diffuse and/or widely distributed entryways. Also, bats could be inadvertently trapped inside if an important exithole, mistakenly identified as a minor one, is sealed in an attempt to limit the number of entryholes requiring an exclusion device. The purpose of this study was to evaluate polypropylene birdnetting as a batproofing tool to overcome the aforementioned difficulties with exclusion devices.

MATERIALS

Polypropylene birdnetting was originally developed to protect high value crops from bird damage (Conwed 1981b) and has also been used as a barrier in structural bird damage control (Conwed 1981a, Salmon and Gorenzel 1981). The product utilized in this study was Conwed® Birdnet Plastic Netting, manufactured by and supplied by the Conwed Corp., St. Paul, Minnesota; a small amount of netting was also supplied by Bird-X, Inc., Chicago, Illinois. The netting is made of durable polypropylene resin, black in color, and treated with ultraviolet stabilizers to extend its serviceable life to about 7 to 8 years (Conwed 1981a, Lann, pers. comm.); durability may be less than 5 years in some hot, dry climates (Martin, pers. comm.). The material is designed to maintain its form so that individual strands will not collapse under stress; it softens at 148.9°C (300°F) and melts at 171.1°C (340°) (Lann, pers. comm.) The netting is available in two grades--structural, with a diagonal hole opening of 1.6 cm (5/8 in), weight 52.3 (1.8 oz)m^2 (10.8 ft^2) and is somewhat stiffer than standard, with a diagonal opening of 2.4 cm (15/16 in) and weighing 16.0 g (0.56 oz)/m^2 (10.8 ft^2). Structural grade was found most suitable for bat work and is available in rolls 4.3 m (14 ft) wide by as long as 914.4 m (3000 ft). Smaller pieces of netting are available from Conwed's distributors and from various individual suppliers of bird control materials.

Waterproof duct tape (7.6 cm [3 in] wide) and common staples (various lengths depending on substratum) were used to attach netting to slate, tin, or asphalt shingle roofs; brick walls or chimneys; and wood or metal clapboards, soffits, moldings, etc. In some cases, split-shot lead sinkers (7 to 41 g) were attached to the bottom edge of free-hanging netting to prevent wind from collapsing the opening used by bats to exit; for similar reasons nylon or other line was used in some other cases to anchor the checkvalves to nearby objects and/or the structure.

METHODS

From among the hundreds of requests for assistance in 1984/85, the final choices for field test sites were based on numerous factors including the existence of a sizeable bat colony; feasibility for one person to complete the exclusion work (with occasional assistance from homeowner or lab assistant); extent of existing bat "damage" (e.g., bat commonly in living quarters, odor, stains on house exterior); relative stress on building's occupants; and architectural variety that would sufficiently test the new method's adaptability. Five residential structures were selected for this study; all had a history (5+ to 25+ yr) of bat infestation by maternity colonies of *M. lucifugus* and/or *E. fuscus* (ranging in size from 150+ to 1,500 bats), all were older than 100 years except one (40 yr), and all were within a 70 mi radius of our laboratory.

To estimate relative colony size and locate points of egress, a standard batwatch was usually conducted for a night or two, sometimes supplemented with observations at dawn. Where appropriate, additional direct observations were made in the roost areas of attics during the daytime. All direct observations were aided by use of a rechargeable SL-15 Streamlight™ (15,000 cp; Streamlight, Inc., Norristown, Pennsylvania) equipped with a plastic, red pop-off filter (~ equivalent to Kodak Wratten 89B), an accessory from a Justrite™ electric headlamp. Bats are sensitive to light intensity and can visually discriminate different shapes and patterns in extremely low light situations (Fenton 1983, Hill and Smith 1984). However, bat retinas lack cones and they see only in black and white. The low-contrast illumination and soft shadows produced by red light has little effect on insectivorous bats.

Based on batwatch and indoor observations, the points of egress currently in use by bats were carefully noted and other holes and structural defects were sealed shut or otherwise closed to varying degrees. Birdnetting was attached to buildings in such a way to function as checkvalves; that is, bats were able to exit freely, but upon attempting re-entry they failed to negotiate the barrier-effect of the netting configuration. The exact method of fitting the checkvalves to a structure depended upon the nature of the entryhole or holes, architectural detail, and the approach flight of the bats. Basically, the checkvalve design required attaching the netting to a structure above the exithole(s) in such a way that its inherent stiffness allowed it to project clear of the hole(s) and not impede the bats exodus. The side portions of the netting were also attached to the structure so as to form an open-bottomed box, sleeve, or skirt (Figures 2, 3, and 4). The width of the checkvalve was highly variable depending largely on the number of holes to be covered. The length, distance from bats' point of egress to bottom edge (horizontal plane) of netting, was usually about 1 m (3.3 ft).

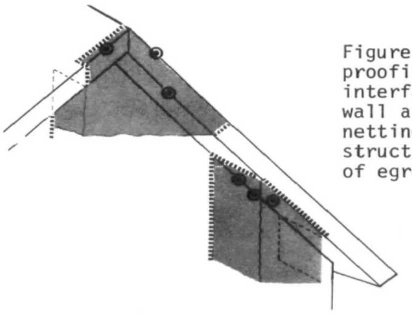

Figure 2. Open-bottomed box designs for batproofing roof apex, roof corner, and associated wall/soffit interface and facia board. Key: shaded area = netting; broken line = attachment to structure; circled bullets = points of egress.

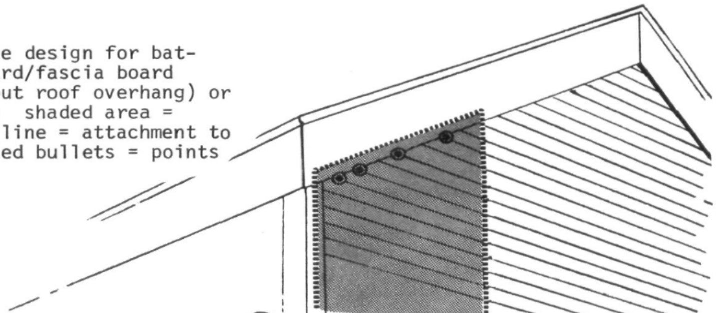

Figure 3. Sleeve design for batproofing clapboard/fascia board interface (without roof overhang) or wall area. Key: shaded area = netting; broken line = attachment to structure; circled bullets = points of egress.

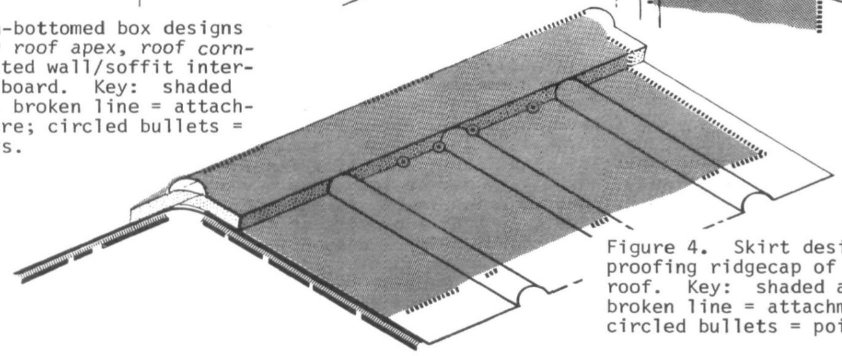

Figure 4. Skirt design for batproofing ridgecap of tin roof or tile roof. Key: shaded area = netting; broken line = attachment to structure; circled bullets = points of egress.

RESULTS

The birdnetting checkvalves of Figures 2, 3, and 4 all allowed bats to readily exit at dusk. With the "box" design (Figure 2) most bats came out of their customary exit holes, dropped freely into the air (in their normal exit behavior), and flew away. Before flying, some animals crawled onto the net for a few moments; a few animals hit the net, or landed on it momentarily, or tumbled out the bottom. After flying free of the checkvalves, bats occasionally flew back toward the exithole, hovered there and/or flew away again. With the "sleeve" design (Figure 3), bats were required to crawl (between the netting and the building wall) to the bottom of the checkvalve before flying. The bats' response to the modified sleeve design, or ridgecap "skirt" (Figure 4), also varied. Most came out from the ridgecap exithole and rapidly slid, crawled and/or glided with the pitch of the roof and went out the bottom. Some crawled about under the net before eventually finding their way to an open trough of the tin roof and out the bottom of the netting.

In no case were bats driven indoors; that is, no bats entered the living quarters during the course of this study. When a few animals encountered the netting, they bit it, stuck their head through the mesh opening, and/or retreated back into the exit hole (presumably to exit later). No animal became entangled or trapped in the checkvalve netting per se; however, two juvenile bats at one site and one adult bat at another site became entrapped in a cul-de-sac of netting where it had been used as a simple barrier. Considering the fact that at least 2,500 bats were excluded from the five sites, the safety record was good for both the bats and the buildings' occupants.

The predawn return of the bats to the roostsite was often dramatic because of the great number of bats found circling about, especially at times of year when the dawn return is highly synchronous. Most bats flew about in clusters near the checkvalves, often landing on the net momentarily, sometimes crawling about the entryhole, then becoming airborne again. The angle of approach of most bats to entryholes was acute with respect to the horizontal, hence they landed quite near (within several centimeters) or at the actual hole. They did approach from different directions (front and sides) which made it important to fully enshroud the entryholes, extend the netting back under the soffit, and attach it to the house wall where necessary (Figure 2). Since the bats approached in a shallow flight angle and landed on or very near the entryholes and stayed there only momentarily, they were unable to find the bottom openings of netting boxes, sleeves, or skirts. In only one instance did a bat enter the bottom opening of a box design and fly in a tight spiral upward to the entryhole. However, this case involved an unusually large "circular" checkvalve (approx. 0.9mdia at bottom x 1.5 m long) attached under a very wide soffit. Further re-entries were prevented by narrowing the bottom diameter to about 0.5 m.

The importance of the bats' angle of approach and use of alternative entryholes was underscored at one site with vertical split-log siding arranged in several tiers, each about 1 m long. The bats were initially using entryways of only the highest tier where it intersected the soffit; accordingly, the box and/or sleeve checkvalves applied were all about 1 m long. However, as soon as the normal entryways were blocked, the bats moved to those of lower tiers which sometimes allowed them to also find their way into the opening of the installed checkvalve. Bat urine stains on the lower tiers suggested that bats had alternative entryways and the study simply forced the bats to verify this for us. The checkvalves needed to be applied in a way that covered all known and possible openings; which translated to constructing sleeve or box checkvalves extending from the eaves to just below the second floor. This was an exceptional case where bats could enter hundreds of openings anywhere on the wall of the second level. The only solutions were to replace the siding (very costly materials) or apply the netting (cost of netting = US $0.70/$m^2$ or less, depending on size purchased).

One of the most surprising successes was with a modified sleeve, or "curtain," design applied to the edge of a shallow-pitched slate roof with a wide (1.25 m) soffit. Bats were using a slit opening between the fascia board and slate shingles at a corner of the roof. Birdnetting was extended about 30 cm to either side of the hole and attached to the upper surface of the slates and to the vertical surface of the fascia board (about 12 cm from top to bottom), with another 15 cm of netting hanging free below the fascia board. The exodus of bats was unremarkable and at their return many landed on the netting but did not find their way around or under it. This result may indicate that some other checkvalve designs could be simplified or it may be directly attributable to entryhole location and architectural factors.

After intial attempts to re-enter holes with checkvalves in place, most bats flew elsewhere, although some persisted for at least an hour into the dawn. Although all excluded bats could not be accounted for, some were observed to enter adjacent roosting sites, barns or other outbuildings, that were in use previously but by fewer numbers. Some animals of indoor (attic) colonies shifted to roosting in more exposed niches, e.g., between an exterior wall and chimney of the original site. In one case, four bats roosted for 1 day under a wide soffit at the wall/soffit interface and against the attached edge of a checkvalve. Presumably, these were newly volant young without experience of the alternative roosting sites which were within 20 m of the original site and into which many other members of the colony had retreated at dawn.

Where birdnetting checkvalves were applied to structures to deny bats re-entry, success was total. This is not to say that this technique can always be rapidly completed (recall the case with split-log siding), but in most typical situations bats could be excluded overnight with birdnetting checkvalves when closure of unused/minor holes precedes such installations. It would be expected that small numbers of bats may sometimes not be manageable as was reported by Barclay et al. (1980) for late summer/early autumn bats in Ontario.

Birdnetting checkvalves will continue to function as long as their attachments to the structure remain secure. Durability has been mixed in these northeastern U.S. field tests. Designs which were protected by eaves or were largely attached by staples have remained intact for as long as two seasons. Unprotected designs and those relying largely on duct tape for attachment have tended to loosen with extended exposure to sun, rain, and snow accumulation. The recommended intervention is to install checkvalves to exclude bats over a period of a few days to a week and to then remove the netting and permanently seal those particular points of egress.

DISCUSSION

The checkvalve principal is unique among bat exclusion devices in that it is a passive design, i.e., nothing needs to move, collapse, or otherwise close to exclude the bats. The denial of re-entry is based primarily on what appears to be a behavioral quirk; that is, when encountering an entryhole at which the visual, auditory, and olfactory characteristics are largely unchanged, bats will try to enter the hole, will not explore to the perimeter of the netting, and will ultimately go elsewhere. It is suggested that a major reason bats continue to return to a treated exit hole *per se* (rather than find a way around it) is because air flow and odor cues from the house have remained virtually intact (as in the preintervention condition). Based on these cues, bats probably perceive the points of egress as still available for re-entry.

When Constantine (1982) attached rigid or semirigid tubes of plastic over entryholes, returning bats were attracted to and were able to enter the 4.9-cm dia open end. Apparently, odor and/or air flow functioned as cues to the tube openings located about 24 cm from the original entryway. Bat entry was thereby prevented through use of a collapsible plastic tube; the same principle applied to his collapsible slot guard. Air flow is not likely to be influenced by the EX-100 Hanks Bat Excluder which is constructed mainly of plastic mesh. If bats should negotiate the cone's 3-cm dia opening, a plastic flapper-valve is to prevent their entry. With birdnetting checkvalves, odor/airflow is not impeded or directed and bats apparently try to re-enter based on these cues. Bats, including M. lucifugus and E. fuscus, have an impressive array of glands and secretions of largely unknown functions (Fenton 1983, Hill and Smith 1984, Kunz 1982). Some species use wing gland secretions to mark their living space, males of some species use chest glands to mark their females, and some species have distinctive body odors. Olfaction is known to play an important part in mother-infant recognition in several species, and group odors produced from guano and urine deposition may also be important in promoting contact between individuals (Kunz 1982). Although bats use a combination of spatial familiarity, acoustic, and visual cue to locate roosts, the current research suggests that olfaction may also be important for location and selection of entryholes.

The fact that bats excluded from particular entryholes, or a roosting site altogether, went to alternative holes and sites was an expected result. Bats commonly maintain familiarity with more than one roosting site which may be adjacent to or distant (a few kilometers) from one another (Christian 1956, Fenton 1983, Krutsch 1946, Kunz 1982, Schowalter et al. 1979) as demonstrated by direct observation, by marking animals (Ryberg 1947), and by radio-tracking (Brigham 1983, 1985). Alternative roosts may be in other building attics or of other types, e.g., trees; behind shutters or signs on a building wall; in barns; etc. The use of such roosts, or shift to such roosts, has been reported to occur in response to human disturbance as well as other factors including change in available food resources, weather change, roost overrun with honeybees, etc. Roost fidelity tends to be strongest during the maternity period and weakest after young are weaned. Tuttle and Stevenson (1982) report that roost selection is extremely important in determining the survival of juvenile bats and displacement may lead to increased mortality if suitable roost sites are limited. In the Northeast, roost sites do not appear to be in short supply for the highly adaptable commensal species. However, this information further underscores the need to avoid intervention for the period after parturition and until weaning. With large bat populations, application of checkvalves over a period of a few days may be less stressful in that fewer animals might be displaced on any particular night and more time would be alloted for adaption to alternative roosts.

There is no reason to suspect that application of birdnetting checkvalves as suggested herein would lead to a dispersal of rabid bats thus creating new problems. Rabies has been found in bats throughout this continent and in all species adequately sampled (Constantine 1979). However, extensive sampling studies indicate an overall infection rate of only a fraction of 1%. Finding one rabid bat in a colony does not indicate that the remaining animals are infected (Trimarchi and Debbie 1977). The utilization of alternative roosting sites in response to exclusion (by checkvalves or other exclusion devices) conducted during the proper low-stress periods of bat development should not present a human risk beyond the norm. The same cannot be said for most lethal interventions which tend to disperse and ground bats (Barclay et al. 1980, Clark et al. 1978, Constantine 1979, Fenton 1983, Greenhall 1982, 1983; Hill and Smith 1984, Hurley and Fenton 1980, Kunz et al. 1977, Tuttle and Kern 1981), thereby leading to increased contact rates with humans and pets which can continue over a number of years as bats continue to utilize traditional roosting sites (unless the site is batproofed). Furthermore, lethal measures could result in a rebounding, lower-aged population of bats at a particular site (Trimarchi pers. comm.). Such individuals would be less likely to have naturally occurring antibodies to rabies (i.e., be more susceptible to rabies) and could more easily result in a rabies outbreak. Fortunately, such artificially induced rabies epizootics have not been reported to date. At any rate, killing is difficult to justify given the low incidence of rabies in bats which are otherwise valuable in control of insects.

CONCLUSIONS

Birdnetting checkvalves were designed and effectively applied to exclude commensal bats from buildings or other structures. Bats were able to make their normal exodus at dusk without becoming entangled or trapped in the checkvalve netting. Upon returning to the roosting site at dawn, bats were not able to circumnavigate the checkvalves, apparently because major cues for re-entry were not impaired, Although exclusion will result in bats utilizing alternative roosting sites, this should not be problematic if installation guidelines are followed regarding proper timing at periods of low biological stress.

Birdnetting is relatively inexpensive compared to major structural modifications, and checkvalve fabrication can be completed during the daytime requiring only commonly available tools. Installation can generally be completed by one or two people within a few days. The designs are adaptable to a wide variety of points of egress: small or large, discrete or diffuse, on a pitch or horizontal, edge or ridgecap or roof, under soffits, around corners, etc., and do not interfere with house ventilation or aesthetic characteristics. Although the polypropylene birdnetting will endure climatic conditions for several years, the effectiveness of checkvalve fabrications will depend on the durability of the method of attachment to structures. Temporary installations are recommended (for getting bats out), closely followed by permanent closure of entryholes.

Most importantly, birdnetting checkvalves permit effective exclusion of bats to be completed while a building is inhabited by bats and people (and their pets), apparently without increasing the risk of bat/human contact. Future studies will include improved attachment methods and attempts to further simplify checkvalve design.

ACKNOWLEDGMENTS

I wish to thank the many people who allowed me to work in their homes and assisted in this effort. I am especially indebted to the families of Albach, Hall, Halloran, Lamb/Stein, Stedman, and the Schoharie

Colonial Heritage Association without whose cooperation this study would not have been possible. Thanks are also due to R. Lord, New York State Office of Historic Preservation, for the rendering of Figure 1. Finally, the Conwed Corp. (St. Paul, Minnesota) and Bird-X, Inc. (Chicago, Illinois) are acknowledged for providing the birdnetting.

LITERATURE CITED

ANONYMOUS. 1983. Wisconsin firm develops bat excluder. Pest Contr. Technol. 11(6):74.

ANTHONY, E. L. P., M. H. STACK, and T. H. KUNZ. 1981. Nightroosting and the nocturnal time budget of the little brown bat, *Myotis lucifugus*: Effects of reproductive status, prey density, and environmental conditions. Oecol. 51:151-156.

BARBOUR, R. W., and W. H. DAVIS. 1969. Bats of America. Univ. Kentucky Press, Lexington. 286 pp.

BARCLAY, R. M. R., D. W. THOMAS, and M. B. FENTON. 1980. Comparison of methods used for controlling bats in buildings. J. Wildl. Manage. 44(2):501-506.

BRIGHAM, R. M. 1983. Roost selection and foraging by radio-tagged big brown bats (*Eptesicus fuscus*). Bat Res. News 24(4):50-51.

BRIGHAM, R. M. 1985. The function of commensal roosting by *Eptesicus fuscus*. 7th Internat. Bat Res. Conf./3rd Eur. Bat Res. Symp. Joint Mtg., Univ. Aberdeen, U.K. 19-24 Aug. 1985.

CAGLE, F. R., and L. COCKRUM. 1943. Notes on a summer colony of *Myotis lucifugus lucifugus*. J. Mammal. 24(4):474_492.

CHRISTIAN, J. J. 1956. The natural history of a summer aggregation of the big brown bat, *Eptesicus fuscus*. Am. Midi. Nat. 55(l):66-95.

CONSTANTINE, D. G. 1979. Bat rabies and bat management. Bull. Soc. Vector Ecol. 4:1-9.

CONSTANTINE, D. G. 1982. Batproofing buildings by installation of value-like devices in entryways. J. Wildl. Manage. 46(2):507-513.

CONWED. 1981a. Structural bird damage control. Conwed Corp., St. Paul, MN. 2 pp.

CONWED. 1981b. Conwed bird damage control netting applications. Conwed Corp., St. Paul, MN. 4 pp.

CORRIGAN, R. M. 1984a. Bat control. Nat. Pest Control Assoc. Tech. Rel. 6/14/84. 12 pp.

CORRIGAN, R. M. 1984b. Nuisance bats: Current technology in their management and control. Pages 174-179 *In*: Eleventh Vert. Pest Conf. (D. O. Clark, Ed.), Sacramento, CA.

DAVIS, W. H., and H. B. HITCHCOCK. 1965. Biology and migration of the bat, *Myotis lucifugus*, in New England. J. Mammal. 46(2):296-313.

DYMOND, J. R. 1936. Life history notes and growth studies on the little brown bat, *Myotis lucifugus lucifugus*. Canad. Field-Nat. 50:114-116.

FENTON, M. B. 1983. Just bats. Univ. Toronto Press, Toronto. 165 pp.

FRANTZ, S. C, and C. V. TRIMARCHI. 1984. Bats in human dwellings: Health concerns and management, Pages 299-308 *In*: Proc. First East. Wildl. Damage Control Conf. (D. J. Decker, Ed.), Cornell Univ., Ithaca, NY.

GREENHALL, A. M. 1982. House bat management. Resource Publ. No. 143. U.S. Dept. Interior, FWS, Washington, DC. 33 pp.

HANKS, M. undated. Introducing the EX-100 Hanks bat excluder. Bay Area Bat Protection, Sturgeon Bay, WI. 6 PP.

HILL, J. E., and J. D. SMITH. 1985. Bats, a natural history. Univ. Texas Press, Austin. 243 pp.

HARLEY, S., and M. B. FENTON. 1980. Ineffectiveness of fenthion, zinc phosphide, DDT and two ultrasonic rodent repellers for control of populations of little brown bats (*Myotis lucifugus*). Bull. Envir. Contam. Toxicol. 25:503-507.

KRUTZSCH, P. H. 1946. Some observations on the big brown bat in San Diego County, California. J. Mammal. 27(3):240-242.

KRUTZSCH, P. H. 1961. A summer colony of male little brown bats. J. Mammal. 42(4)529-530.

KUNZ, T. H. 1982. Roosting ecology of bats. Pages 1-55 *In*: Ecology of Bats (T. H. Kunz, Ed.). Plenum Press, NY.

KUNZ, T. H., E. L. P. ANTHONY, and W. T. RUMAGE, III. 1977. Mortality of little brown bats following multiple pesticide applications. J. Wildl. Manage. 41:476-483.

LERA, T. M., and S. FORTUNE. 1980. Bat management in the United States: Survey of legislative actions, court decisions, and agency interpretations, Pages 207-212 *In*: Proc. 5th Internat. Bat Res. Conf. (D. E. Wilson and A. L. Gardner, Eds.), Texas Tech Press, Lubbock, TX.

MARSH, R. E., and W. E. HOWARD. 1977. Vertebrate control manual. VII. Bats. Pest Control. Oct. 1977: 24,26,28,32,35,36,50.

MORANO, M. F. E. 1964. An account of a remarkable accumulation of bats. Smithsonian Ann. Rep. for 1863:407-409.

PHILLIPS, G. L. 1966. Ecology of the big brown bat (Chiroptera: Vespertilionidae) in Northeastern Kansas. Am. Midi. Nat. 75(1):168-198.

RYBERG, O. 1947. Studies on bats and bat parasites, Vol. I. Bokforlaget Svensk Natur, Stockholm. 330 pp.

SALMON, T. P., and W. P. GORENZEL. 1981. Cliff swallows: How to live with them. Univ. Calif. Coop. Exten. Leaflet 21264. 7 pp.

SCHOWALTER, D. B. 1980. Swarming, reproduction, and early hibernation of *Myotis lucifugus* and *M. volans* in Alberta, Canada. J. Mammal. 61(2):350-354.

SCHOWALTER, D. B., and J. R. GUNSON. 1979. Reproductive biology of the big brown bat (*Eptesicus fuscus*) in Alberta. Canad. Field-Nat. 91(3):48-54.

SCHOWALTER, D. B., J. R. GUNSON, and L. D. HARDER. 1979. Life history characteristics of little brown bats (*Myotis lucifugus*) in Alberta. Canad. Field-Nat. 93(3):243-251.

TRIMARCHI, C. V., and J. G. DEBBIE. 1977. Naturally occurring rabies virus and neutralizing antibody in two species of insectivorous bats of New York State. J. Wildl. Dis. 13:368-369.

TRIMARCHI, C. V., and S. C. FRANTZ. 1985. Bat control. New York State Dept. Health (Albany) Pamphlet, n.p.

TUTTLE, M. D., and S. J. KERN. 1981. Bats and public health. Contrib. Biol. Geol. No. 48. Milwaukee Publ. Mus. Press, Milwaukee, WI. 11 pp.

TUTTLE, M. D., and D. STEVENSON. 1982. Growth and survival of bats, Pages 105-150 *In*: Ecology of Bats (T. H. Kunz, Ed.), Plenum Press, NY.

WHELDEN, R. M. 1941. Hibernation of *Eptesicus fuscus* in a New Hampshire building. J. Mammal. 22:203.

WIMSATT, W. A. 1970. Biology of bats. *Vol. II.* Academic Press, NY. 477 pp.