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The Bat House Study

Since many people are interested in participating in BCI's ongoing research on bat houses and have an active interest in the process of scientific discovery, we report here the data and reasoning that led to our conclusions.

SAMPLING METHODS

Our study was conducted by calling 420 people in 26 states and one Canadian province who had put up a total of 416 bat houses. Of these, 276 had been monitored sufficiently to be included in our survey. One hundred and forty houses had not been checked and four had not been erected; therefore no data could be obtained on these.

A survey data sheet was completed for each bat house, regardless of whether it had been used, and all details were carefully re-checked by phone. Information collected on the data sheets allowed us to evaluate the effects of house size and shape, treatment with paint or stain, the kind and age of wood used, the mounting substrate, height above ground, and location. Location considerations included urbanization, distance to lakes and streams, hours of solar radiation, distance to nearest flight path obstacles, forest density, and the presence of nearby agriculture. Conclusions drawn from these data were then tested to determine significance. When sample results are reported as differing significantly, this means that a chi-square statistical test indicated the odds of a difference as large as noted in our data could be expected to occur by chance alone less than five times out of a hundred.

We conducted two surveys. The first includes 143 houses and is based on follow-up calls to BCI members who had previously reported either success or failure with a bat house. The second group includes 133 houses and consists mostly of non-BCI members who had erected bat houses they built from plans received from various sources or purchased ready-made from non-BCI vendors. We identified this group through referrals from biologists from state departments of natural resources, colleagues, nature centers, and BCI members. In both cases, equal efforts were made to reach all identified bat house owners, regardless of known or suspected success or failure with their houses.

Ninety-three percent of the bat houses surveyed were patterned after six basic designs popularized through BCI publications [see illustration, opposite page]. Seventy-nine percent of these contained vertical partitions, had open bottoms, and varied little except in size. Spaces between partitions ranged from 3/4" to 2", but were mostly 3/4". Only 12 very large houses were surveyed, including nine of the Missouri style.

In order to determine the effect of house size on occupancy rates, we grouped all houses, regardless of design, into four categories. The following sizes are based on external measurements:

1) SMALL (11" to 14" tall X 7" to 8" wide X 6" to 7" deep), Models 1-3.
2) MEDIUM (22" tall X 8" wide and deep *or* 21" tall X 9-1/2" wide X 2" deep), Models 4-5.
3) LARGE (a vertical design, 25" to 36" tall X 10" to 24" wide X 5-1/2" to 11-1/4" deep, *or* a horizontal design 12" tall X 32" wide X 5-1/2" deep), Model 6.

4) VERY LARGE (Missouri-style, 2'5" tall X 4' wide X 7'6" long, each roosting crevice limited to 12" X 12"), not illustrated.

RESULTS AND DISCUSSION

Occupancy rates and colony sizes— BCI members achieved significantly higher success rates (64%) than nonmembers (44%). Nonmembers often had built or purchased bat houses without adequate instructions, and they were 10% more likely to build or purchase the smallest sizes, which proved least successful.

Since the two groups were of similar size and represented a full spectrum of bat house types and results, we combined them for purposes of analysis. This permitted greatly increased sample sizes (and therefore accuracy) for statistical comparison of the various factors determining bat house occupancy. The results show an average occupancy rate of 52% for the 276 bat houses included in this study. Use rates varied among the six basic bat house models, shown below.

Only nine Missouri-style bat house reports were obtained in time to be compared to the full set of criteria, but 13 more were reported in time to be useful in determining occupancy rates for this design. Our sample size would have been much larger, but a high proportion of builders misinterpreted the plans and left out the horizontal ceiling above the roosting chambers. No such incomplete houses are known to have been occupied by bats, and these were excluded from our survey. Missouri-style houses built exactly according to the original plans were only 39% occupied, a surprisingly low rate compared to other houses of much smaller size.

Survey participants estimated the numbers of bats by looking into the house (94%), counting emerging bats (5%), or seeing droppings beneath the roost (1%). When they counted emerging bats, they reported an average of 53 per house as compared with 33 for visual inspections. Since most counts resulted from looking into the houses, real numbers of bats were probably underestimated. Bats cluster toward the top and observers often cannot see the innermost individuals.

Colony sizes for small bat house Models 1 to 3 averaged 28 bats and ranged from one to 150, though the most frequently reported numbers were just one to five. Colony sizes for the medium-sized Model 4 houses averaged 21 bats and were used most frequently by colonies of 21 to 30 bats; the largest colony sizes reported for this model were between 31 and 50 individuals. Model 5 houses averaged 14 bats per house and were used by from one to 150 bats. Colonies attracted to Model 6 houses averaged 29 bats and ranged from one to 250. The much larger Missouri-style houses, as originally designed, averaged colonies of 65 bats, ranging from eight to 250.

Despite its large size, the Missouri-style house is not well suited to the preferences of bats in that each 3/4" crevice is only 12" X 12". Results of this study indicate that bats, especially nursery colonies, prefer larger roosting chambers, which permits more bats to roost in contact with each other. This preference likely explains the relatively high use rate achieved by the much smaller Model 4 bat houses as opposed to the larger Missouri-style.

Eleven bat houses that relied on basically the same designs as Models 3, 5, and 6, but that provided longer roosting chambers, had the highest occupancy rate at 73%. These houses averaged 24" to 36" tall X 16" to 24" wide X 4" to 5" deep *or* 12" tall X 32" wide X 5-1/2" deep. The longer houses held average colonies of 100 bats, ranging from 13 to 250.

Use patterns Occupancy rates for bat houses built and put up by different people varied greatly with placement, especially when erected in areas of differing bat habitat and needs. These uneven patterns clearly explain much of the controversy over whether or not bat houses work and emphasize the need for broad-based sampling.

Among the eight largest samples reported by individual people who had erected multiple bat houses, use rates varied from 0 to 96%. For example, at one Oregon location, none of 18 houses placed on trees in dense forest were occupied, while 23 of 24 at another Oregon site attracted bats when placed both outside and inside a barn and on poles at the edge of woodlots. The only one not used was mounted on a shaded tree trunk.

Time until first occupancy We had long believed that bat houses were most likely to be occupied after at least one or two seasons had passed, but this study found exactly the opposite. Most houses used by bats were occupied in the first season. Eighty-five percent were first used within two seasons and only 15% in the third through sixth seasons. Of eventually occupied houses, the time from installment to first occupancy averaged as follows:

Time Lapsed	***Occupancy Rate***
<1 month	24%
1 to 6 months (through 1st summer)	46%
1 year (through 2nd summer)	15%
2 years	11%
3 years	2%
4 years	1%
5 years	1%

Species occupying bat houses Most of the houses in this study were erected by laypeople who could only guess at a bat's identity. However, bats from 37% of the occupied houses were positively identified by biologists or photographed well enough to permit identification by us. Of these, 82% were used by little brown bats (*Myotis lucifugus*), sharing at least 7% with big brown bats (*Eptesicus fuscus*) and 3% with eastern long-eared myotis (*M. septentrionalis*). Texas houses were mostly occupied by Mexican free-tailed bats (*Tadarida brasiliensis*), including as many as 150 in a single small house. A colony of between 30 and 50 pallid bats *(Antrozous pallidus*) occupied another small house in Arizona.

It is highly probable that additional species occupied bat houses without being positively identified. For example, many of the bats reported from Georgia and Florida are outside the normal range of little brown bats and are almost certainly southeastern bats (*Myotis austroriparius*). Some could also be evening bats (*Nycticeius humeralis*). Bats were reported using bat houses in a Texas locality where mist netting has revealed only this species.

How bats use bat houses Most people feared disturbing their bats, so they did not check at night to determine if young were present. Also, few people considered checking their houses in winter. Nevertheless, of 45 houses where inspection was adequate to determine

the kind of use, 33% were used by nursery colonies, 60% by bachelor colonies, and 7% for hibernation.

Only little brown and eastern long-eared myotis were confirmed to be rearing young in bat houses, though others probably did without being identified. Few nursery colonies in this study were believed to consist of less than 50 adults. If we assume that nursery colonies typically do not number fewer than 50 adult bats, then our data would suggest that less than 18% of bat houses currently might be used for nursery purposes. However, easily made adjustments could greatly increase this proportion [see "Designing Better Bat Houses," page 16].

Big brown bats were found hibernating in a Texas bat house that was located on the west side of a building where it was apparently too hot for summer use. They were also found hibernating in bat houses in Kentucky and New York and are suspected at a site in Nebraska.

Effect of wood type There is no evidence from our data to indicate that any kind of wood is objectionable to bats. Occupancy rates based on the kind of wood used are as follows (samples of less than 10 houses built of a particular wood are excluded from this comparison):

# Bat Houses	***Wood Used***	***Occupancy Rate***
142	Cedar	54%
77	Pine	53%
21	Cypress	29%
19	Exterior plywood	74%

The apparent preference for plywood is likely because its availability in large sheets enables construction of longer and taller houses, which bats prefer.

Effect of age of wood and treating with guano Occupied houses made of old versus new wood were compared for timing of first use. Bats were significantly more likely to move into houses during the first season if they were made of old wood. Of comparable houses first made available in spring and eventually occupied, eight houses made of old wood were all used in the first season, compared with only 32 of 65 houses made of new wood. Age of wood affected only the timing of the first use, not the probability of use.

The effect of treating bat houses with guano could not be statistically tested from available data since many people who treated with guano also used old wood. One bat house builder reports that his well-established and growing colony typically expands quickly into new houses made of old wood or treated with a solution of bat guano diluted with water. His bats have twice waited until the second season to occupy houses made of new, untreated wood. Other builders, however, report that houses made of new, untreated wood have been occupied as soon as the first night.

Seventeen of 18 houses located in ideal areas and treated with bat droppings dissolved in water were occupied in the first six months. Droppings were collected from the same species living in the immediate vicinity. There is little other evidence to support the idea of earlier occupancy for treated houses.

Guano treatment, at best, seems only to hasten the timing of first occupancy of a new house and apparently does not affect the overall probability of use.

Effect of urbanization and agriculture Our sample included only 21 houses put up in an urban environment. Of these, 48% were used, which is surprisingly close to the overall average.

Bats exhibited a significant preference for houses located in agricultural areas. Such houses had an occupancy rate of 88%, compared with the average of 52% for all areas combined. These areas were mainly orchards interspersed with a variety of other land uses. Our sample did not include any houses placed where large areas were planted in single crops.

Effect of water source Bat houses located a quarter of a mile or less from streams or rivers had an occupancy rate of 78%. The size of the river was not a significant factor, though there was a slight trend toward better occupancy near larger rivers. Our results indicate a significant preference for houses located near streams or rivers, even when compared with large lakes. (Very large lakes, such as Lakes Michigan or Superior, are not compared in our sample.)

Where lakes were the dominant water source, bats significantly preferred houses near those of three acres or more. These houses were 62% occupied versus 28% near lakes or ponds covering less than three acres. Bats using artificial roosts in arid areas of the Southwest likely would be less influenced by the size of the water source.

Effect of paint or stain Although bat researchers have long believed that painting or staining a bat house might repel bats, we did not find this to be true. In fact, bats living in cool areas (for purposes of comparison, at latitudes north of 40o) show a significant preference for houses with an exterior either stained dark or painted black.

Sixty-seven percent of darkened northern houses were occupied, compared with an occupancy rate of 44% for those left plain. Covering houses with tar paper achieved similarly positive results. We do not yet know where, moving south between 40o and 35o, darkening houses would begin to have a negative effect. The darkening of bat houses is, of course, closely related to solar heating, in that the effects are additive.

Effect of solar radiation Exposure to sun is one of the most important criteria identified in this study for determining use of bat houses. We knew that bat needs would vary according to geographically differing ambient temperatures, but found that temperature cannot be accurately predicted based on mere knowledge of latitude and altitude. For purposes of this investigation, we divided North America into three zones: 1) all localities at latitudes north of 40o; 2) all localities between 35o and 40o; and 3) all localities south of 35o.

We then compared bat house occupancy rates according to sun exposure in each of the three geographic zones. Since the hours of sun exposure reported were assumed to be only rough approximations, we arbitrarily divided our samples into houses receiving four or more hours of daily sun versus less than four hours.

Houses, with or without dark stain or tar paper covering, were significantly more likely to be used north of 40o if they were exposed to four or more hours of sun. Those receiving more than four hours of sun were 83% occupied, compared to 26% for those with less than four hours. No amount of sun appeared to be too much for northern houses, but in

interpreting results, one must consider that they mostly reflect the preferences of little brown bats. Big brown bats may prefer less.

At mid-latitudes, there were no houses in our study that had been darkened. Houses built of plain, untreated wood could not be statistically tested for solar exposure preferences due to small sample sizes. However, of 12 comparable houses receiving more than four hours of sun, 67% were occupied, compared with 60% of five that received less. This exhibits the expected trend toward less need for solar heating the farther south a house is located.

No houses surveyed at latitudes south of 35o were darkened, and sample sizes again were too small for statistical comparison. Nevertheless, of the seven comparable houses receiving more than four hours of daily sun, only 43% were occupied, compared to 59% for the 10 houses receiving less. All six southern houses that were hung on the sides of buildings and received zero to two hours of sun were occupied.

Effect of height above ground Bats in this study clearly preferred houses that were highest above ground, but this factor may not be independent of exposure to sun:

# Houses	***Height***	***Occupancy Rate***
25	<10'	40%
214	11'-15'	50%
27	16'-20'	63%
10	21'-30'	70%

Effects of dense forest and distance to nearest obstacles The 28 bat houses located in dense forest had occupancy rates significantly below average. These were only 18% occupied compared to 52% for the study at large.

At latitudes north of 40o, the distance of a bat house to the nearest potential flight obstacles, usually tree branches, was significantly related to occupancy. Those less than five feet from obstacles were only 24% used, compared to 76% for those 20 feet or more from obstacles. As will be discussed, forest density, distance to nearest obstacles, and exposure to solar heating are not independent.

Effect of Mounting Substrate Occupancy rates differed significantly among houses mounted on buildings, poles, or trees. All data, regardless of latitude, were included in this comparison. Houses located on poles were 81% occupied and those on buildings were 73% used, while those placed on trees (whether isolated or in a forest) achieved only 34% success. Sixty percent of the sample was northern, 6% mid-latitude, and 34% southern. As we learned, mounting substrate and exposure to solar heating are closely related, and bats often are not actually choosing a particular substrate, but rather exposure to sun.

Relevance of solar radiation to dense forest, obstacles, and mounting substrate Looking at the data showing highest occupancy rates on poles and least in dense forest, we hypothesized that exposure to sun might explain these differences. Indeed, we found that houses mounted on poles received an average of nine hours of daily sun, compared to seven for those mounted on buildings and only two hours on trees.

We further found that nearby obstacles, usually tree branches, significantly reduced the

amount of sun reaching houses. Only 4% of 24 houses located five feet or less from obstacles received four hours or more of daily sun, compared to 61% of 28 houses that were more than five feet away.

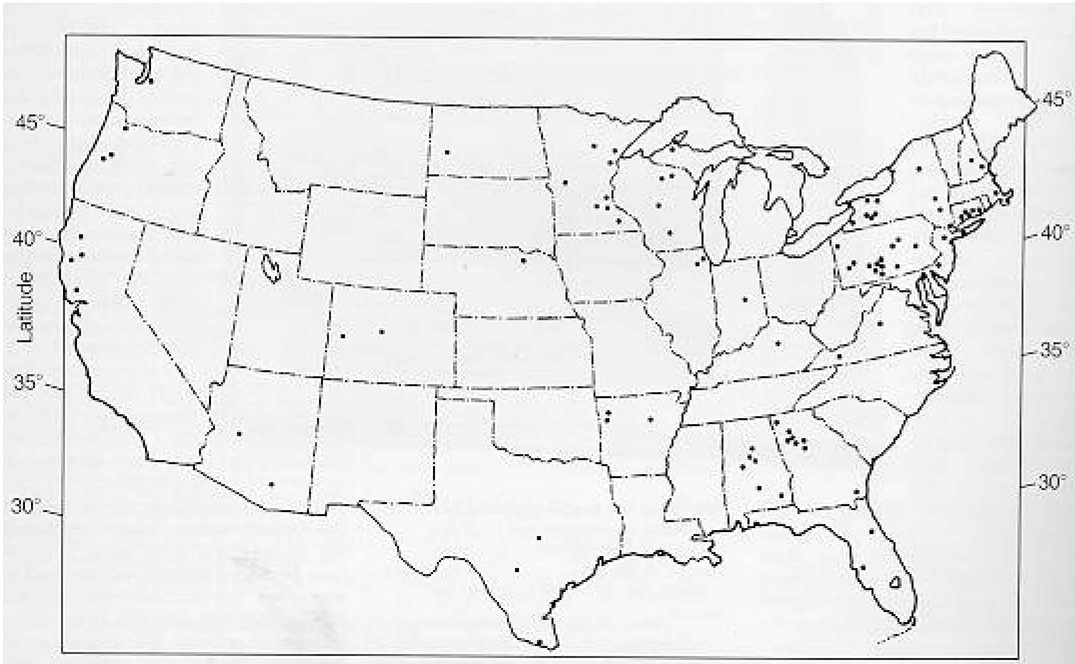
Exposure to the sun appears to be more important than actual nearness of branches and other clutter. The only house that was less than five feet from obstacles, but still received more than four hours of sun, was occupied despite the clutter. Europeans have noticed reduced use of bat houses mounted in mature forest, but they have ascribed this negative relationship to greater availability of alternate roosts. Our data suggests a lack of solar heating as a primary factor.

To test our hypothesis, we predicted that if reduced solar heating were the primary determinant of low use rates for houses on trees, tree-mounted houses receiving more than four hours of daily sun would have use rates comparable to those mounted on buildings or poles. Knowing that bat needs for solar warming may be opposite in northern versus southern localities, we limited this test to houses at latitudes north of 40o.

We found that northern houses mounted on trees, but still receiving four or more hours of sun daily, were significantly more likely to be occupied than those receiving less. In fact, such houses achieved occupancy rates of 82%, compared to 81% for poles and 73% for buildings. It seems clear that the mounting substrate is not as important as hours of exposure to solar heating.

Assuming too little sun to be the reason for poor occupancy rates on trees, we postulated that houses on southern trees should be better used than their northern counterparts. Indeed, occupancy rates for houses on southern trees proved to be significantly higher than for those on northern trees. The 17% improvement likely would have been even greater except that little brown bats are uncommon in the South, while Mexican free-tailed bats are among the most frequent users of southern houses. Free-tails are high-speed flyers that may be less likely to risk flying into the increased obstacles around many tree-mounted houses. Thus far, they are only known to use houses mounted on buildings or poles.

BCI greatly appreciates the help of the many members and friends who tested their bat houses under a wide variety of conditions and locations and who patiently reported on the results. Special thanks also to Dr. Michael Ryan, professor of zoology at the University of Texas-Austin, for his invaluable assistance in analysis of these data.



This map shows the geographical distribution of the study and depicts locations of the 276 bat houses included in the survey, whether occupied or not. Many of the people surveyed erected multiple bat houses.

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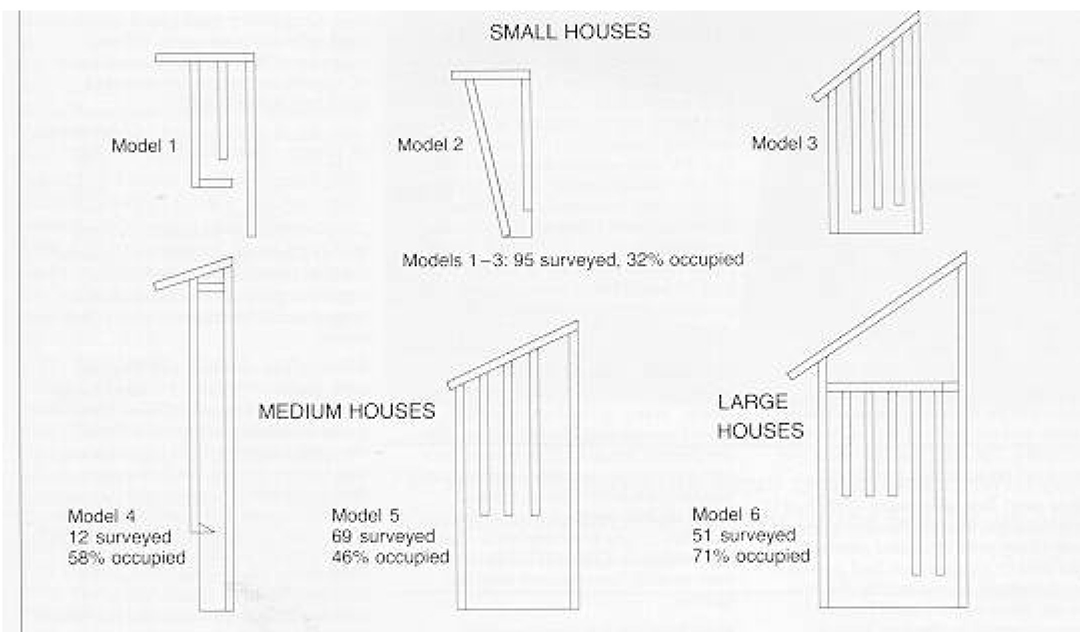

The majority of bat houses in the survey were patterned after these six basic designs, which have appeared in various BCI publications over the past 10 years. To determine the effect of size on occupancy success, they were further grouped into four basic size categories, each of which had many variations. As shown, certain designs were more successful in attracting bats than others, but larger size, especially providing longer and taller roosting chambers, appeared to be important factors.

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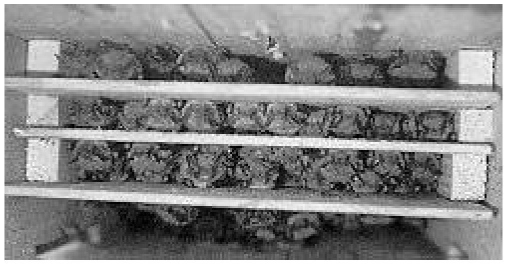
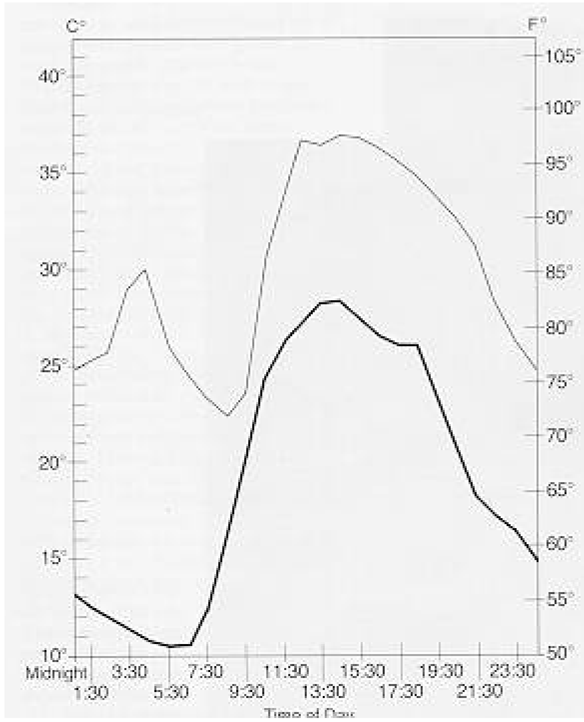


A surprising number of houses sheltered nursery colonies, some of them 200 or more bats in a single house. This one is shared by both little brown bats and eastern long-eared myotis.

Once bats had left these houses at one of Lisa Williams' study sites in the fall, she installed thermocouples in the crevices to obtain a record of how each chamber reacted to ambient temperature. Her studies revealed much about the temperature needs of nursing bats in bat houses. In summer these boxes house about 350 little brown bats that were excluded from a nearby building.



This graph compares internal bat house temperatures with ambient temperature throughout a 24-hour cycle in one of Lisa Williams' study houses, which was occupied by a nursery colony of little brown bats. The open-bottom house, which contained five 18- to 24-inch tall partitions, was covered with black tar paper and exposed to at least four hours of sun daily. Bats chose the central chambers where internal temperature was best buffered from the external. Temperatures in occupied crevices remained in the preferred 80- to 90-degree range for at least 12 hours of the cycle and at 90 degrees or above for seven hours. They fell below 80 degrees for only five hours in early morning.

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