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ROOST SELECTION OF *NYCTALUS NOCTULA* (CHIROPTERA, VESPERTILIONIDAE) IN URBAN HABITAT

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Abstract: The paper summarises the investigation of roost-selection of *Nyctalus noctula* (Schreber, 1774) in panel buildings in Hungary. From September 1997 until July 1999 we explored 142 roosts on a 103 ha large housing estate. Blocks of flats provide excellent roosts for bats throughout the whole year. Bats prefer roosts at the height of 6-8 metres (64% of the roosts) without any seasonal differences. Results show that there are no bat roosts below the height of 3 metres. Half of the roosts are on the vertical corners of the buildings (within 1 metre). This may be caused by the wider holes behind the corner-panels. The width of the used entrance is 19 mm minimum. The position of vegetation and road around the buildings do not influence the roost selection. In the summer 35% of the roosts are situated on the western walls. The rhythm of temperature fluctuation on this side best corresponds to the daily activity cycle of bats. In winter bats prefer the southern walls, where the temperature is significantly warmer on a sunny day, than on the other sides. The inner temperature on a cloudy day is also warmer in occupied panel holes than in uninhabited panel holes. It is caused by the warmth escaping from the heated rooms because of poor insulation. The estimated density of the common noctules' population is 24 ind./ha, which is higher than in a natural forest, because of higher density of available roosts.

Key words: Chiroptera, *Nyctalus noctula*, roost selection, urbanisation

INTRODUCTION

In the last decades more and more bats inhabit man-made constructions, such as buildings and bridges. Some species use almost exclusively these constructions for roosts (eg. *Pipistrellus pipistrellus*: THOMPSON 1992, *Plecotus auritus*: ENTWISTLE *et al.* 1997). The urbanisation gets impulses from two sides. In one respect bats are forced to move into towns due to disapperance of traditional roosts, and on the other hand, the urban grounds ensure advantageous roosting and foraging habitats.

The disappearance of old forests goes together with the disappearing of roosts of forest-dwelling bats. Furthermore, deficiency of roosting possibilities is worsened by the fact that competition between birds and bats may increase while the numbers of tree holes decrease (MASON *et al.* 1972).

Several authors tried to describe the conditions of suitable bat roosts. The roost has to fulfill several requirements. It provides protection from the extreme weather conditions (VAUGHAN 1987) and predators (FENTON 1983). In a safe roost bats can devote their energy to social interactions (MORRISON 1980). In the temperate zone the temperature of the roost has a strong impact on survival (HUMPHREY 1975). Summing up, it can be stated that characteristic features of roosts have a significant impact on the survival and fitness of bats (VOHNHOF and BARCLAY 1996). Nevertheless, it may happen that inhabiting a roost is attached to the special role of the building, for example, using the roost may be related to the fitness-optimalization in such way that foraging or drinking areas are not distant (TUTTLE 1976, SPEAKMAN *et al.* 1991, ENTWISTLE *et al.* 1997).

Although there are many publications dealing with the biology and behaviour of *Nyctalus noctula* (SLUITER *et al.* 1973, KLAWITTER and VIERHAUS 1975, GAISLER *et al.* 1979, ROBEL 1982, HEISE 1985 and others), many of the ecological and behavioural relationships are still unclear.

In Hungary noctule bats inhabit a peculiar roost type different in many ways from the traditional one. In Hungary the noctule is the most urbanized bat species. Its second main roost type occurs in blocks of houses in panel gaps.

We investigated whether noctules select among these special roosts. We raised the question which environmental conditions make bats inhabit panel buildings.

MATERIALS AND METHODS

Study area

The investigation was carried out in the biggest town (250,000 inhabitants) of East-Hungary. The town called Debrecen is located 120 m above sea level. The study area is a housing estate. It is surrounded by houses with gardens and also prefabricated panel buildings. There are trees and bushes around the blocks of flats and public buildings (schools, nursery schools, etc.).

The territory of the area is about 103 hectares, which consists of 195 panel buildings. The smallest building is 4 metres high, and the tallest block of flats is 18 metres high. The housing estate is situated close to the forest called Nagyerdő (1.5 km). There are several oak trees more than 100 years old in the forest. Bats also live in their hollows.

The housing estate was possibly inhabited by bat colonies living in the nearby forest. A small pond in the forest provides the nearest drinking possibility for bats.

The structure of artificial roosts: The panel

In the 1960s in Hungary the state started a constructional program for blocks of flats. Since the speediness was an important factor, the use of prefabricated panels became common. The panels have a special 'sandwich' structure in the interests of heat insulation. The cross section of the wall has four layers. Between two concrete coatings there is a cavity with air and foam-rubber (Fig.1).

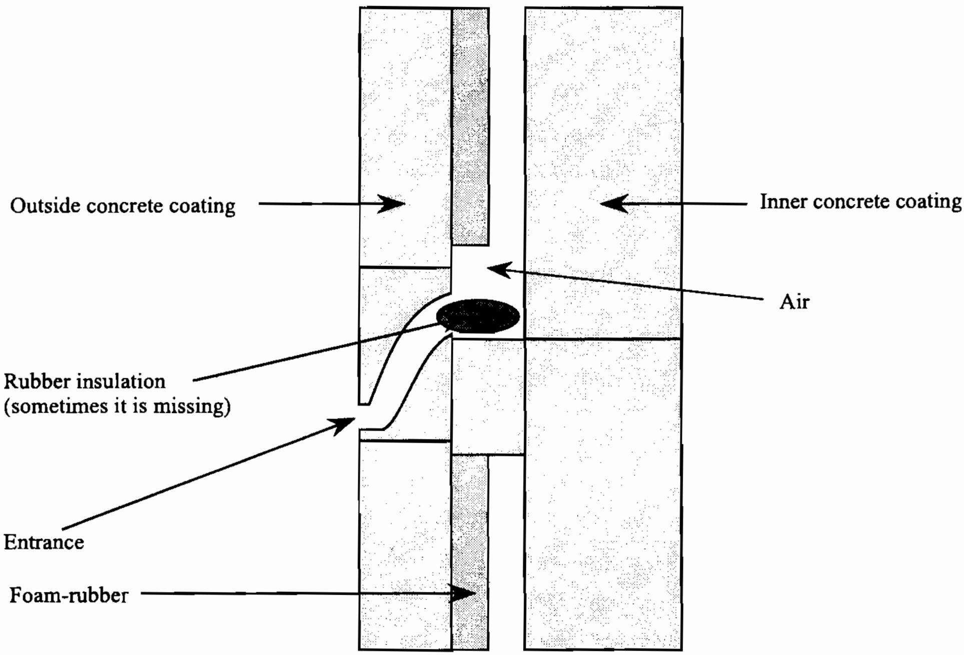

Fig. 1. The 'sandwich' structure of a panel (cross-section).

There are horizontal and transversal connecting panel edges with 2-8 cm wide gaps among the 2 m high and 2 m wide panels. Normally these gaps are insulated. If the insulation is missing, there is a possibility for bats to occupy the holes inside the wall (Fig. 2). The panels are quite often fitted together badly or even damaged, which makes the panel hollows accessible for bats.

On the housing estate two main panel types are in use. One of them is called 'mosott' panel. The high blocks of flats have this structure. The other panel is called 'festett', which is used for public buildings.

The species studied

Nyctalus noctula occurs all over Europe up to the southern parts of Scandinavia. It is the most frequent bat species in Hungary. It never stays in caves and does not form colonies in attics. It is a typical forest-dwelling species (VAN HEERDT and SLUITER 1965). In Hungary the number of old trees is decreasing, mainly because of inadequate silviculture. This means that there are less and less natural roosts for those animals living in tree holes. Adaptable species (like the noctule bat) are in advantage. In the last decade they changed their habitat and nowadays this is the most common species residing in panel buildings in towns. Those colonies living on housing estates use these artificial roosts the whole year round, as both summer and winter roosts. Nowadays it is common that thousands of bats live on single housing estates in Hungary. Besides the noctule bat, the serotine *(Eptesicus serotinus)* and the pipistrelle (*Pipistrellus pipistrellus*) might occur rarely in these special habitats. In Hungary there is an increasing tendency in their numbers.

Method

The examinations were carried out between November 1997 and July 1999. We checked the possible panel hollows where bats might occur on the housing estate. We used MINI-3 bat detectors and checked the foot of the wall to search for bat droppings. By detecting the exact position of the entrance we counted individuals flying out from

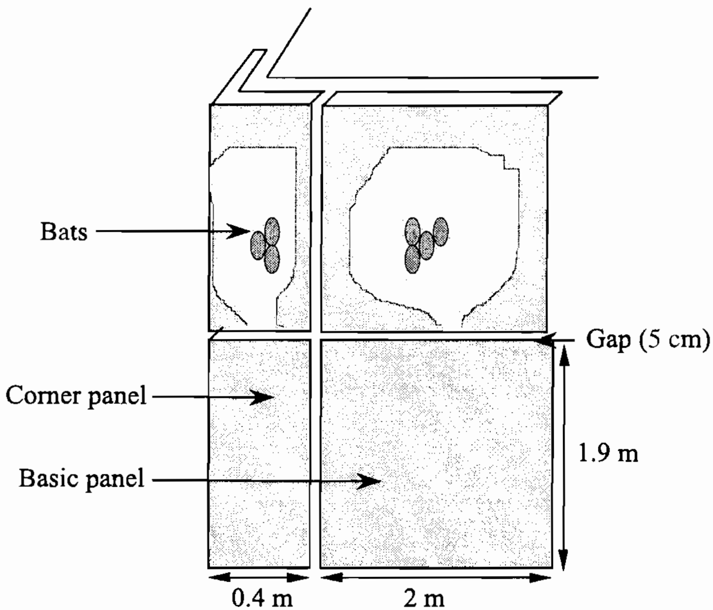

Fig. 2. The position of the prefabricated panels and the possible roost site with the bats.

the roosts. The coloration around the entrance was also helpful. By using the narrow entrance, dirty spots are formed around it caused by the greasy fur and skin and also by the urine and excrements of bats.

We filled in a data sheet. It contains the orientation, the height, distance to corner, characteristics of the entrance and surrounding area of the roost.

Every long gap between panels can be an entrance into the panel hole. We surveyed the gaps at full length in the study area and divided the full length into panel-units. The term panel-unit means a 2 meter long gap. We counted the number of panel-units occupied by bats (Fig. 2).

We also examined whether the distance to traffic and roads plays an important role in roost selection.

The temperatures outside and inside roosts were recorded by traditional and digital thermometers (-20°C, 50°C) both in winter and summer on a sunny and a cloudy day. We read the thermometer every 2 hours. We measured the temperature inside the panel hole in three categories: in roost sites, in random non-roost hollows and in adjacent non roosts as control samples. The last category means unoccupied panel holes which are situated in the same wall where the roosts are. These adjacent roosts obviously have the same local habitat features.

RESULTS

We found 142 panel units which are occupied by noctules on the study area.

1. Structural preference

In the whole housing estate there are 135,971 panel-units. 127,439 units from these are 'mosott' type and only 8,532 units belong to 'festett' type.

131 panel-units of the total 142 inhabited ones were found in 'festett' panel, and only 11 were in 'mosott' panel. Bats significantly prefer panels of the 'festett' type ($G=651.28$, $df=1$, $P<0.001$). Further investigations were carried out only in the 'festett' panels.

2. Size of entrance

The size of entrances along the incorrect fits and broken panel edges play a very important role, because the morphology of bats determine the smallest entrance where the bats can get in. The smallest entrance of roost was 19 mm (19-28 mm).

3. Height preference

We did not find any roost below the height of three metres above ground. The most preferred roosts were between the height of 6 and 8 metres ($G=218.641$, $df=14$,

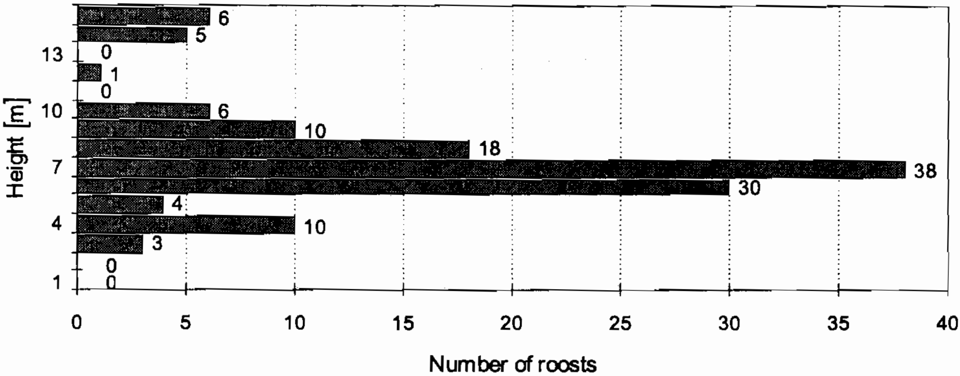

Fig. 3. The relative frequency of height of occurrence of roosts (n=131).

P<0.00001). The majority of roosts could be found in this interval (64% of the total roosts) (Fig. 3).

4. Distance to corner

Half of the roosts were situated within the distance of one metre from the corner. Noctule bats significantly preferred the corner panel (Fisher exact test df=1, P<0.00001). We revealed that behind these corner-panels there were wider inner spaces of about 4-5 cm x 150 cm x 50 cm. Behind the basic panels the inner space was 2.5 cm x 150 cm x 150 cm.

5. Orientation of the summer roosts

The inner temperature of panel hollows varied during the day on the differently orientated walls. Considering temperature, there were no considerable differences among daily maximum temperatures in random panel hollows on differently orientated walls, but temperatures ranged differently on each wall during the day. Temperatures of the southern walls ranged very similarly to the outside temperature. They quickly warmed up parallel to the outside temperature and reached the maximal temperature at 1 p.m. The panel hollows in the western wall warmed up slowly and cooled down later, but not as early as eastern wall temperatures in the afternoon. The temperature peak of the western walls was noted three hours later than in the southern walls (4 p.m.) (Fig. 4). Eastern wall roosts warmed up quickly in the morning, but cooled down earlier in the afternoon.

Between the orientation and the inner temperature there is a strong correlation. In the summer 42% of the roosts were on the western side (n=48), whereas the others situated in an equal proportion (15-28%) on the other sides (Table 1). Bats preferred the western walls of the buildings (G=24.64 df=3, P<0.001).

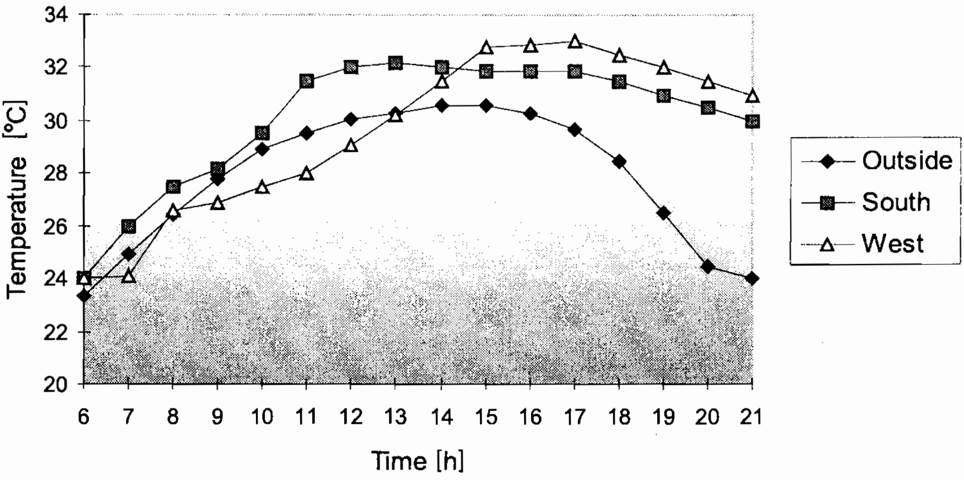

Fig. 4. Temperature in the roosts and outside on a sunny summer day.

Table 1. Orientation of panel units and roosts in summer and winter.

Orientation	Number of panel units	Number of roosts in summer	Number of roosts in winter
Northern	2659	27	6
Eastern	2596	27	5
Southern	1525	28	10
Western	1752	48	5
Total	n = 8532	n = 130	n = 26

6. Orientation of winter roosts

In January the temperature in random panel holes orientated to south was significantly warmer on a sunny day ($T=5.803$, $df=10$, $P < 0.0001$). It was more than two times warmer (14.8°C) on southern walls than on the northern ones (5.5 °C) at the external temperature of 5.4°C (January 1999).

In winter some of the panel hollows were also inhabited by hibernating bats. In 1998-99 we found 26 winterquarters. 38.4 % of them were located on the southern parts of the buildings. The noctules preferred the southern side, but not significantly ($G=6.5$, $df=3$, $P<0.08$).

7. Effects of insulation in winter

In winter the warmth, which escapes out from the well-heated rooms, may have an effect on the temperature of the roosts. At 4.3°C external temperature it was warmer in roosts (median: 7.65°C) than in adjacent hollows (median: 6.05°C) ($Z = -2.52$, $P<0.01$). It is the consequence of heating and not of the body-warmth of bats.

8. Distance to vegetation and roads

The traffic causes very intensive noise at the range of 10-25 KHz. There was no evidence that bats were influenced by noise in roost selection, because almost all buildings were situated near busy roads (Table 2). The situation of trees and bushes did not influence bats significantly, either. However, it might had been advantageous if there were some trees in front of the wall, because it could moderate the power of wind.

Table 2. Distances of roosts from roads and tree-line

Distance from busy roads	Number of roosts	Distance from tree-line	Number of roosts
<50 m	106	<50 m	131
50–100m	6	50–100m	0
100–200m	19	100–200m	0
Total	n=131	Total	n=131

DISCUSSION

From November 1997, until July 1999, we explored 131 roosts in 'festett' panel buildings. 26 of them were also occupied in winter. The results show that there are no bat roosts below the height of 3 metres. The noctule bats prefer the height between 6-8 metres. This height is very similar to the height of tree holes in forests. Half of the roosts are at the corners of the buildings (within 1 metre). This may be so because of the bigger space behind the corner-panels. The width of entrances is also important. Entrances narrower than 20 mm make it impossible for bats to occupy the panel hollows.

We know that the temperature of roosts can have a strong impact on bat colonies. Bats minimalize their thermoregulation costs by selecting warmer roost (ENTWISTLE *et al.* 1997). *P. auritus*, with its 8 grams, could save 1 kJ energy per day (4%) from the 25.5 kJ energy necessary for resting if the roost was warmer of 1.2°C. AUDET and FENTON (1988) proved by radiotelemetry that the non-reproductive specimens of *P. auritus* chose significantly cooler roosts after a rainy, cold night. This cooler alternative roost ensures better conditions for the daily torpor. The warm roost is particularly important at pregnancy (RACEY and SWIFT 1981) and breeding time (TUTTLE 1975) when it helps in survival (RANSOME 1989). However, the warm roost is unsuitable for the daily torpor.

In summer the noctules prefer the roosts situated on the western walls. It may be caused by the fluctuation of temperature which is mostly suitable for the life-rhythm of bats: in the morning, when bats spend their daily resting phase and they are in torpor, the roost is the coolest on this side. The temperature inside the roost located on the western wall reaches the maximum in late afternoon. This is exactly the time when bats become more active and warm their body up. The warmer roost helps in this process, so bats can save energy.

The temperature seems not to be as important factor in winter as we have seen in summer. Bats have no significant preference between the walls, but most of the roosts are on the southern walls, where the internal temperature of roosts can be significantly warmer than on other walls. They prefer those roosts where the insulation is insufficient. In such roosts the internal temperature is higher than in the unoccupied hollows because of the warmth escaping from heated rooms. It is strange because we know that warmer hibernaculum causes higher energy consumption.

It is advantageous when the roosts are located close to trees, forest, since it may give protection to the flying bats against birds of prey (LIMPENS *et al.* 1989, JONES *et al.* 1995). Bats usually fly along linear vegetation, such as a tree-lines (EKMAN and DE JONG 1996, ENTWISTLE *et al.* 1996, WALSH and HARRIS 1996), because it may decrease the danger of predation. This might be the reason for bats to avoid those potential roosts which are isolated and have no forest nearby.

We found that the roost-selection is not influenced by the situation of vegetation around the buildings because bats usually hunt several kilometres far from the roosts and they fly up to 50-100 metres high just after the emergence.

If bats find all necessary conditions, they feel well and form stable colonies. We defined bats staying in one roost a 'split-community'. Bats living in one building or buildings close to each other form one colony. The animals often change their roosts even for one night. We tried to count bats flying into and out of roosts, thus we may say that a split-community usually consists of 15-20 individuals and a colony is formed by about 100 individuals. Density of bats in the studied area is 24 ind/ha. This is higher than in a natural forest (GAISLER *et al.* 1979), which can be ascribed to the fact that the study area provides excellent roosts for noctule bats.

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