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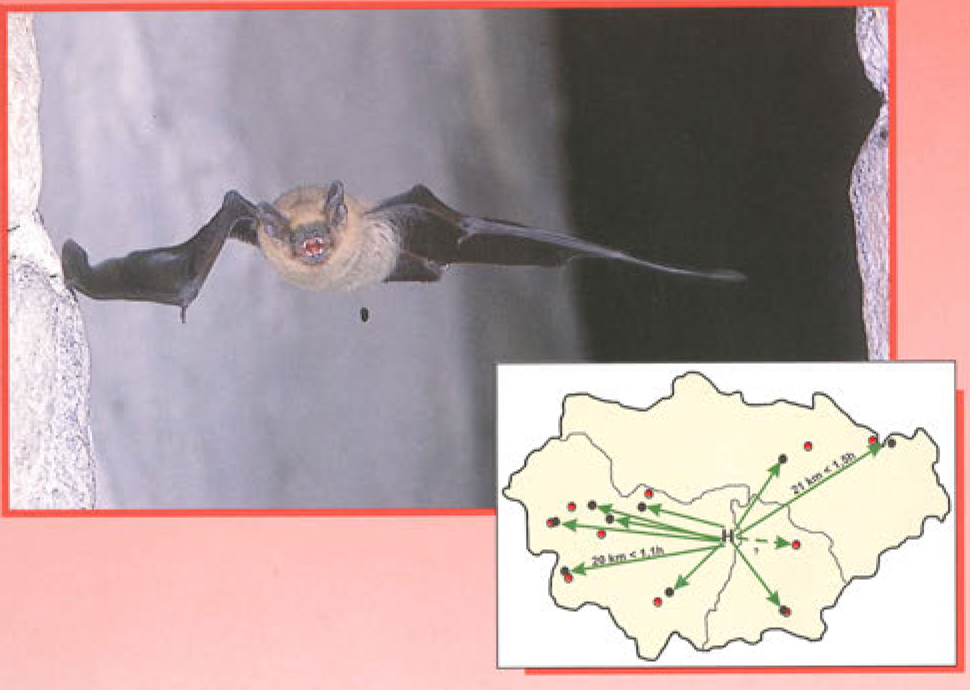
Ecology and Conservation of Bats in Villages and Towns



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Ecology and Conservation of Bats in Villages and Towns

77

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Ecology and Conservation of Bats in Villages and Towns

Results of the scientific part of the testing & development project
"Creating a network of roost sites for bat species
inhabiting human settlements"

Matthias Simon, Sandra Hüttenbügel
and Janna Smit-Viergutz
in collaboration with Peter Boye

Bundesamt für Naturschutz
Bonn - Bad Godesberg 2004

Title page: A common pipistrelle flying through an embrasure into the cellar of Marburg castle. The map shows minimal distances covered by common pipistrelles fitted with transmitters during the summer swarming at the hibernaculum and returned near by or to their origin villages. The distances and flying times are given for two individuals (see figure 88).

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Preface

Bats live a secret life. For those species seeking their refuges close to humans, such a lifestyle has advantages and disadvantages. As there are still householders who will not tolerate these four-legged lodgers because they fear bats will bring dirt and other inconveniences, it is to the bats' advantage that they stay out of sight. However, they are in danger when buildings are renovated, and noone knows that bats are thereby disturbed, driven away or even locked in. This has been the fate of many bats over the last decades, some populations being thus extinguished.

For these reasons a project of testing and development (T&D) was initiated in the mid-1990s, to test effective measures to aid house-dwelling bats. Towards this aim, practical measures to conserve and construct roosts for house-dwelling bats were developed and tested within a main project, while a parallel scientific project analyzed the success of these measures, and investigated the life and ecological demands of these animals in a more detailed way. Both these projects have now been concluded.

The accompanying scientific investigation, whose results are presented here, has brought many new insights into the biology and ecology of bats within the area of human settlements which can be applied on a practical level. Already in the first year of the project the hypothesis could be proved that a colony of bats not only has one roost, but uses a roost assemblage, and changes or switches frequently between these different hiding places. The mystery of bat invasions could also be explained.

The results yielded valuable clues that can be applied to the protection of these secret lodgers. Amongst them, for example, is the insight that bat conservation in the area of settlement requires intensive public relations work, as each element of a roost assemblage can only be conserved if as many householders as possible tolerate their nocturnally active guests.

The T&D Project could not have been carried out so successfully if it had not been for the support of many people. The Department of Animal Ecology at the Philipps University of Marburg and the Wildlife Biology Study-Group at the Justus Liebig University in Gießen took on the responsibility of carrying out the project. The ambitious aims of the accompanying scientific investigation could only be met because of the great number of enthusiastic students from the Universtiy of Marburg, who contributed their time and effort as part of their coursework or undergraduate theses. Finally, the T&D Project found much support in the state of Hesse, particularly in the Marburg-Biedenkopf district and in the city of Marburg. Special thanks should go to the authors of this report, on whom lay the burden of responsibility for the accompanying scientific investigation. They have contributed much to the protection of bats in settled areas.

This report was published first in German as volume 76 of this series. The English version was produced to improve the distribution of the research results in Europe, especially within the community of the EUROBATS Agreement. Translation works were kindly supported by Simon & Widdig Consultancies (Marburg).

We hope that the results from the project find a wide audience, that they be taken into account wherever conservation is practised and that they contribute to improving the current critical situation of house-dwelling bats.

Federal Agency for Nature Conservation

Contents

1 Introduction

The idea of a federal T&D project with the aim of "Creating a network of roost sites for bat species inhabiting human settlements" was developed at the beginning of the 1990s. After many years of decreasing bat populations in Germany, there was an increasing willingness in the public to support the survival of these fascinating mammals by specific conservation measures. At the same time, alarming news arrived from the new German federal states, where broad programs of restauration were underway which threatened the previously advantageous living conditions for bats that had existed in the former GDR. Thus, it was of nationwide interest to investigate the requirements and possibilities for the conservation of bats and their habitats in human settlement (compare BOYE 2002). In order to cover a sufficient sample of the native bat fauna, a relatively vast T&D project area was chosen, namely the administration district of Marburg-Biedenkopf in central Germany (DIETZ & SIMON 1999).

The project started out with two assumptions: firstly, we were convinced of the fact that in principle it is possible to combine bat protection with modern building and living. Secondly, we supposed that bat colonies in a village or area of a town will be distributed among various roosts, and that the groups could be bigger if they had a larger number of roosts at their disposal. The main goal within the testing and development project was therefore to secure as many existing bat roosts as possible, and to create new ones. The participation of householders had to be gained via targeted public relations work. The results and experiences of the main project, and the practical knowledge thereby gained, have already been processed and published by DIETZ & WEBER (2002).

At the fore of the scientific part of the T&D project was the testing of the hypothesis that bats use numerous roosts combined into a roost assemblage and that a targeted increase of potential roosts in urban areas leads to a long-term enlargement of bat stocks. At the time the project was planned, very little was known about the dynamics of the use of maternity roosts by bat species. That was why the roost requirements of each different species had to be investigated in more detail. In addition, it was the duty of the scientific project part to provide advice to those working on the T&D project part which implemented the building measures necessary for the construction of roosts. The investigations that are reported here had the following aims:

- The development and application of new methods to record and observe bats.
- The identification of roost requirements of house-dwelling bats.
- An adequate quantitative recording of bat stocks within large parts of the investigation area.
- Research into the special behaviour of bats to search for and scout roosts.
- The supervision of new potential roosts built in houses.
- An evaluation of the new roosts in buildings and of other possibilities for bat conservation within human settlements.
- The systematic investigation of roost switching behaviour whereby bats move from one roost to another.

During the course of the project many more specific questions were raised which were deepened as much as possible. Genetic relationships between bats were analyzed in order to prove the exchange of specimens amongst colonies. Furthermore, ecological aspects of landscape ecology were also taken into account for the analysis, that is to say, the surroundings of the settlements. To achieve this aim, numerous bats were investigated by telemetry. During the years 1997 to 2001, a great number of post-graduate theses were written or encouraged at the Philipps-University Marburg (within the T&D project) which dealt with bats and had special aspects or parts of the T&D project as their content. They are tagged with a (*)

in the literaturelist. They formed an important part of the current investigations. A project group of about 6 to 10 people could thus collect and evaluate extensive data continously over several years. The amount of data gained exceeded all expectations, so that some details have not yet been analyzed satisfactorily. A very good example for the far-reaching possibilities of evaluating the data gained in the project was supplied by SENDOR (2002), who completed his doctorate thesis on the ecology of the population of common pipistrelles at the Marburg Castle. Various post-graduate works also form a central technical basis for applied conservation: thus, a Natura 2000 site of about 10,000 ha could be proposed to protect the Barbastelle bat within the project area.

2 Area of Investigation

The area of investigation is situated in central Hesse in the Marburg-Biedenkopf district. It has a total area of 1,262 km² (see Figure 1). This area is divided into 9 municipalities and 13 rural shires. The rural shires contain a total 161 villages and hamlets. The human population density of the district in the year 2000 was 198 inhabitants per km². The largest settlements are the university city of Marburg (approx. 77,400 inhabitants) and the town Stadtallendorf with approx. 21,600 inhabitants.

The largest percentage of productive land is taken up by agriculture at 45 %. Around 40 % is covered by forest, and 12 % is taken up by farm yards, buildings, roads, lanes and other open areas. The percentage of water surface area is 0.9 % of the total area (KREISAUSSCHUSS DES LANDKREISES MARBURG-BIEDENKOPF 1996). The largest river in the district is the Lahn, which has many branches. The major tributaries of the Lahn are the Ohn, Wetschaft, Wohra, Perf and Klein rivers.

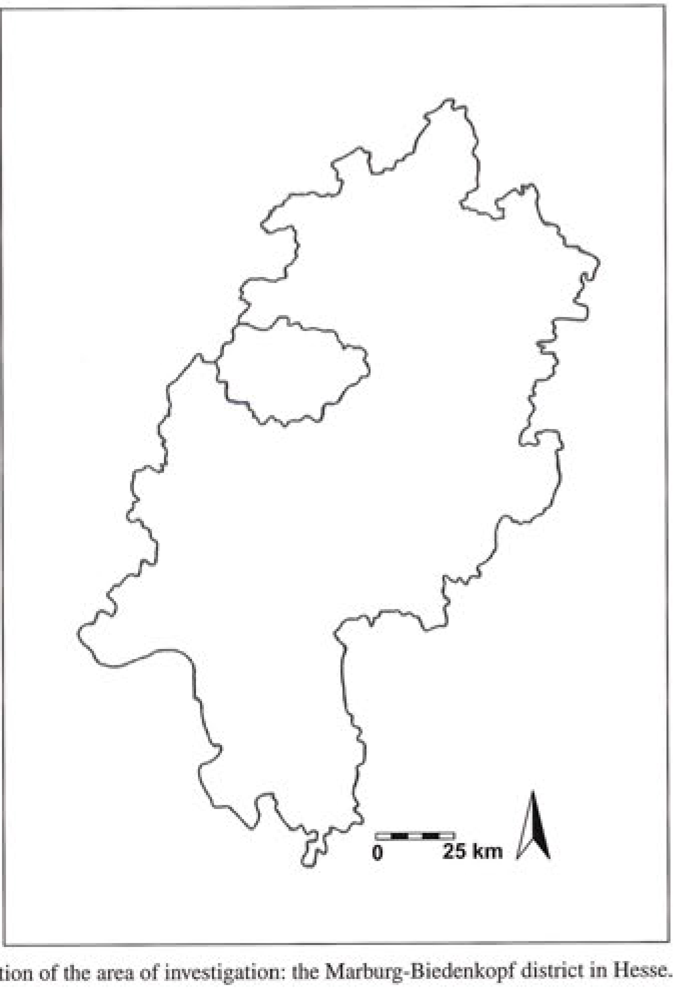

Figure 1: Location of the area of investigation: the Marburg-Biedenkopf district in Hesse.

2.1 Landform of the Marburg-Biedenkopf district

The district has a landscape designated "hill and basin". Natural features divide the district into three areas: to the west are the high Rhein Slate Mountains which progress to the east into the West Hesse hill and valley country and then to the foothills of the East Hesse Ranges (from KLAUSING 1988). The highest peak in the district is the "Sackpfeife", 674 m above sea level, situated in the foothills of the Sauer Highlands, on the district's north-western border. The "Sackpfeife" is situated between the river valleys of the upper Lahn (approx. 280 m) and the upper Eder (approx. 340 m).

Positioned approximately in the middle of the eastern slopes of the Marburg Ridge is the old city of Marburg, and in it the Marburg Castle (290 m a.s.l.).

2.2 Climate

Hesse is given the climatic designation sub-oceanic, cool temperate forest (PLETSCH 1989). The regional climate is designated mild, warm-temperate wet. The mean annual temperature in the hinterland (Gladenbach Ranges) is 6–7 °C and in the Marburg area (Lahn and Ohm river valleys, Ebsdorf valley) is 8–9 °C (see figure 2). The mean annual precipitation also bands the difference in climate between the hinterland and that in the Marburg area, with 850–1,000 mm in the former and 600–700 mm in the latter (KREISAUSSCHUSS DES LANDKREISES MARBURG-BIEDENKOPF 1996).

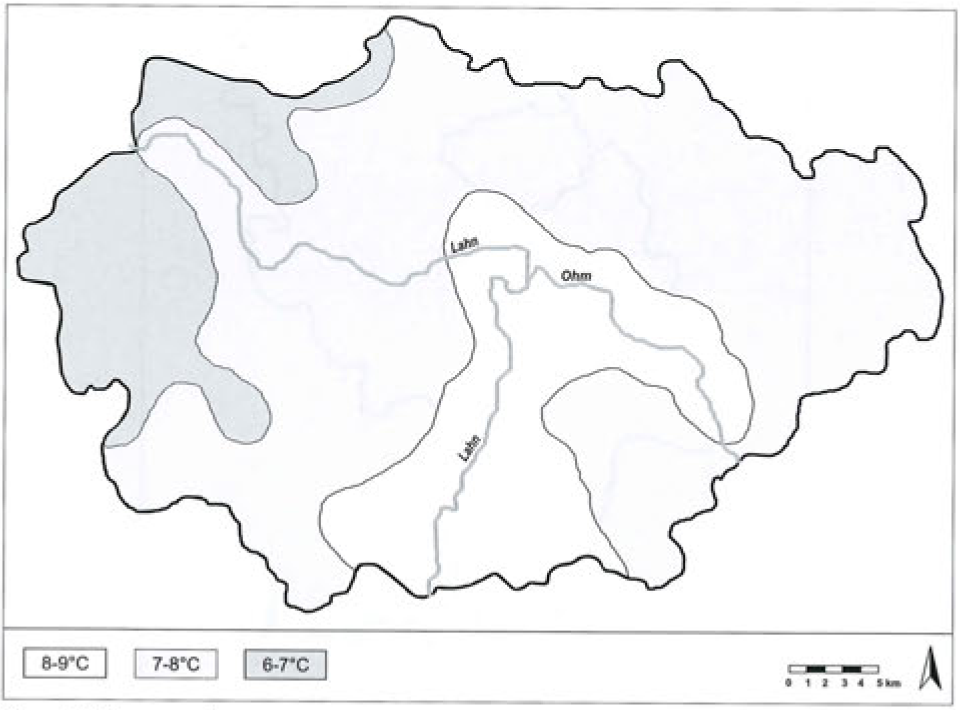

Figure 2: Mean annual temperature (schematised according to the Hesse Climate Atlas, MOTHES-WAGNER 1992).

2.3 Landuse

The largest tract of unfragmented forest is the Brücker Forest in the north of the district (see figure 3). To the east, beyond the forested Lahn Ridge, is the open country of the Amöneurg Basin, which is largely agricultural. This is adjoined further to the south by the Ebsdorf Valley, also characterised by open country. Both these areas of open country are used for grazing and cropping. The western part of the district is characterised by a high percentage of forested area which is, however, highly fragmented forest.

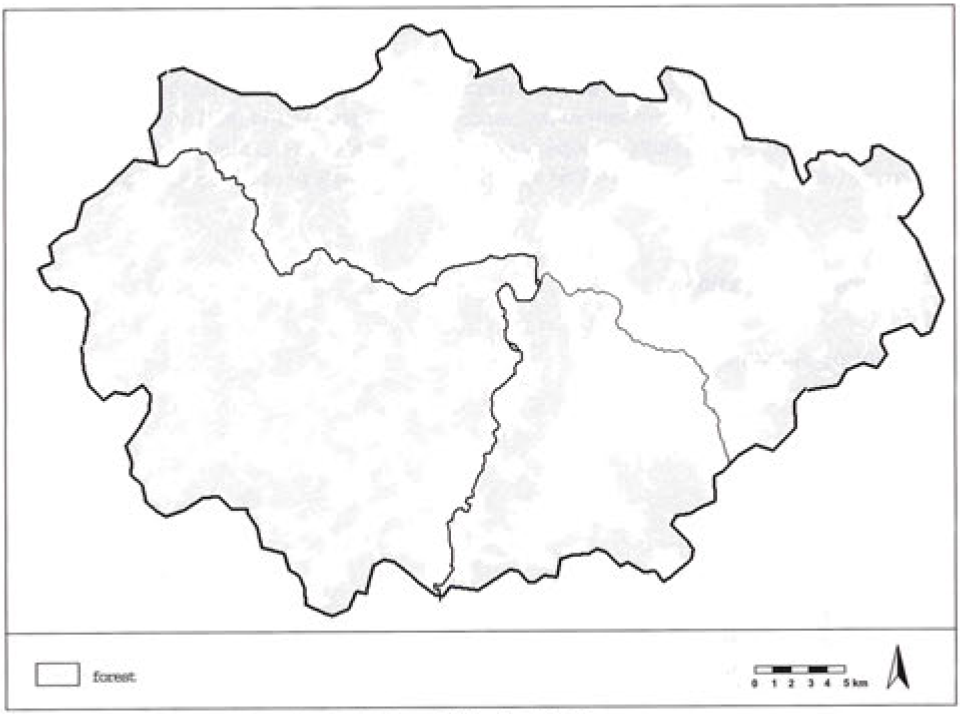

Figure 3: Distribution of forest in the Marburg-Biedenkopf district.

3 Methods – aims, description and evaluation

3.1 Introduction

Investigations of bats have numerous methodological problems. This is not only due to the nocturnal activity and ultrasound orientation of these animals, but also due to their way of moving: the quick flight. Observations during the day are made more difficult by the fact that the animals retire mostly into the tightest crevices and hiding places high up in roofs or facades.

For a long time now few methods and materials have been available for systematic investigations of bats outside the roost. For the success of the investigations within the project, it was necessary to apply the well-known and tested methods systematically, and to develop and test additional new methods or procedures.

The methodological section is divided thematically into recording methods, methods to observe behaviour, methods of automatic surveillance of roosts and methods to measure the roost temperature. Additionally, a population genetics study was carried out. Furthermore, a geographical information system (GIS) was employed to analyze bats' use of landscape structures.

3.1.1 Acoustic detection

Aims:

- Recording of bat numbers
- Locating roosts

Materials:

- Ultra sound detector
- Maps

Procedure and Evaluation

One of the prerequisites for the evaluation of animal populations or partial populations is knowledge about their size.

With bats as other animal groups, there is a low level of knowledge about their natural and local occurrance and population density. The level of mapping within the different regions normally depends on the activity of regional bat experts To evaluate our results and especially to evaluate the significance and efficiency of newly created potential roosts for bats, we first had to know the existing bat numbers. The size of the project area, however, made a complete quantitative recording impossible. For this reason, the aim was to map bat stocks in as many towns and villages as possible, and thus to get representative results for the whole district. At the same time, it was also important to record as many roosts of the various colonies as possible, in order to get an overview of the number of roosts required by a bat colony. Up to now, detector surveys to map bat activities have taken place almost exclusively in the countryside (hunting grounds; landscape elements which can serve as guiding structures; different habitats) (e. g. WALSH & MAYLE 1991, VERBOOM & HUITEMA 1997, ROCHE & ELLIOT 2000). Detector surveys in towns are poorly described in the literature (GAISLER et al. 1998), and was carried out selectively in the green areas of a town (parks; old wood lots), in which the existence of bats was suspected (JANSEN 1993).

To record the house-dwelling bat species within the project area, 345 detector surveys were carried out in 110 villages. To this purpose, a distinction was made between evening, night and morning mapping. Evening mapping can record all bat species emerging from their roost, even though they leave their roosts at different times. Morning mapping makes it possible to find animals swarming at the roost, shortly before flying in (e. g. SWIFT 1980). Depending on the size of the colony, the swarming procedure can last longer than half an hour. The combination of evening and morning mapping in one village makes sense because in the morning it is possible to search in a more concentrated way in those areas in which an evening activity has already been detected. The efficiency of night mapping is especially high during the lactation period, as the adult females return at night to the roost to suckle. They can be observed swarming at the roost already from midnight onwards. Additionally, the social noises made by the young not yet able to fly are heard coming from the roost.

The evening and morning mapping started about half an hour before sunset or sunrise, respectively, and lasted about one and a half hours. The number of mappers was between two to eight people, depending on the size and layout of the town or village (see figure 4). As a rule, the number of people required increased with the size of the area of the village, but its layout was also significant. Each person was assigned certain streets in the village, which were walked several times systematically with a bat detector.

Evening mapping was the most appropriate for recording the roosts of the serotine bat, because this bat species leaves in the evening, usually when it is still light, then flies relatively high and straight, often in groups, into its hunting grounds. Also, serotine bats are heard clearly in the detector, because of their loud calls. Morning swarming is not a common phenomenon of the serotine bat, but only takes place sporadically (see chapter 6.6.3 and chapter 7.2.2). For this reason, morning mapping, which has been reliable for other species, is not appropriate for mapping serotine bats. However, night mapping makes sense at the time when the young leave the roost (from the beginning of July), as the young mostly stay in close proximity to their roosts, and swarm there to scout. During this time, the night recording of roosts of this species is very efficient. For the other species, which have their roosts mainly in buildings (common pipistrelle, whiskered bat, grey long-eared bat, greater mouse-eared bat, Natterer's bat), a morning mapping during time of swarming at the roosts is the most advantageous method. Species like Nathusius' pipistrelle and Kuhl's pipistrelle or the Natterer's bat, which have very quiet calls, can only be recorded well in the morning by employing additional visual observations.

For the recording of Natterer's bats, it is advisable to carry out targeted, nocturnal searches in the cattle sheds of villages (see chapter 4.4.1). On the one hand, these bats use the sheds as hunting grounds. On the other hand, there are also maternity roosts in the hollow spaces

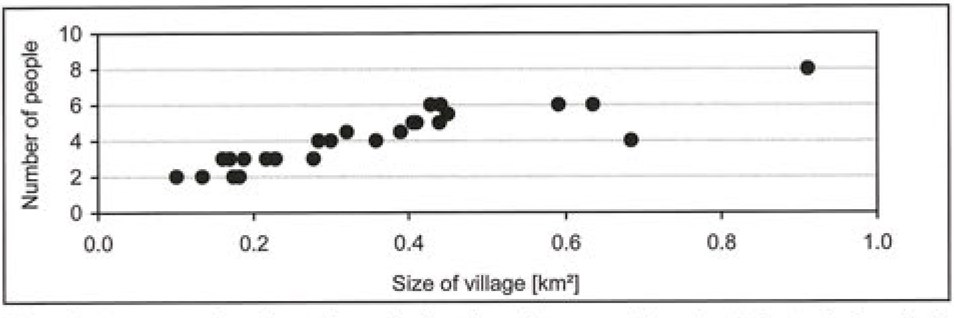

Figure 4: Average number of people mapping bats in each town or village, in relation to the size of village.

in walls or ceilings in the sheds. Natterer's bats have not been detected yet in pig stalls. However, these sheds are seldom accessible to bats from outside. Before mapping, it is advisable to obtain the permission of the local farmers (an open window to the street, through which the detector can be held, is often adequate). This targeted method allows several villages to be mapped one after another in one night, depending on the density of the sheds. The livestock sheds in which nocturnal hunting activity has been detected, should be visited then once more at dawn. Thus, possible roosts can be found. If the bats have their roost somewhere else, the animals may be able to be followed in the direction of their roost. This method promises more success of discovering further roosts.

3.1.2 Emergence observation

Aims:
- Estimation of colony size
- Determination of species
- Determining time and duration of emergence
- Signs of roost switching

Material:
- Ultrasound detector

Procedure and evaluation:

In general, the observation of bats emerging from their roost can be carried out by one person. Nonetheless, complex emergence openings of bigger colonies may require more people. The use of a detector is very important, as otherwise animals can be overlooked, especially at dusk. Depending on the bat species and size of colony, it takes generally up to about an hour to count how many bats emerge after sunset (table 1). Common pipistrelle and serotine bats belong to the species that emerge early, while whiskered bats, Natterer's bats, grey long-eared bats, barbastelle bats and greater mouse-eared bats emerge later.

Table 1: Information concerning the time of emergence for several bat species.

Species	Time of emergence
P. pipistrellus	mean time of emergence at 24.5 min after sunset
E. serotinus	mean time of emergence between 13.3 min and 30.6 min after sunset
P. auritus, P. austriacus, *B. barbastellus*	between 12 and 44 min after sunset, mean time of emergence at 32 +/- 8 min after sunset
M. myotis	between 23 and 45 min, mean time of emergence at 67.2 +/- 17 min after sunset

3.1.3 Capture and banding of bats

Aims:
- Determination of species
- Determining sizes of colony and population
- Proof and investigation of summer roost switching

- Ascertainment of spatial correlation between roosts (summer and winter) over large distances
- Proof of connection between summer monitoring of hibernacula and hibernation
- Establishment of ecological parameters which concern the population (e. g. survival index, age)

Material:

- Mist nets, 70D, 16 mm, 2.5 m x 7 m or 2.5 x 12 m
- Extendable poles, 6 m or 9 m long
- Hinges for extendable poles
- Specially made funnel traps and dip nets (see below)
- Catching container with a cotton bag (with a wide plastic edge)
- Ladder
- Arm clips of the sizes "H", "M" and "X" supplied by a bat banding centre
- Suitable metal rod to pre-bend the arm clips before attatching

Procedure:

Trapping

Basically, there are two suitable methods for capturing bats, depending on the questions wanting to be answered and on the composition of the roost.

- **Catching with a net:** Capture of single bats, e. g. to determine the species, or capture at roosts with big emergence openings, or those with numerous, hard to determine openings (e. g. gallery or slate wall).
- **Catching with funnel trap/dip net** (based on TUTTLE 1974, COTTERILL & FERGUSSON 1993): capture of a great number of bats, which are given armclips to distinguish them, and which are to be recaptured regularly.

As, in order to investigate the roost compound and the behaviour of roost switching, there were to be as many animals captured as possible, the bats were captured almost exclusively with funnel traps and dip nets (see figure 6) in front of their roosts when emerging (see figure 5). When manufacturing the dip nets, the highest possible catching efficiency must be combined with a low danger of injury for the animals. The trapping equipment was designed according to already known funnel traps and dip nets (TUTTLE 1974, COTTERILL & FERGUSSON 1993). The basic form for both types of trapping instruments is a box-shaped metal frame made of high-grade steel or aluminium tubing.

The sides of the frame were spanned with fishing line at intervals of one centimeter, or lined with plastic film. A cotton bag was fixed under the metal frame, to catch and retain the animals. At least half a meter of film was fixed as smoothly as possible between bag and frame, to prevent the bats climbing up. Some of the dip nets had a plastic film "cuff" at the top of the bag to serve as additional climbing barrier.

As the emergence openings are often at great heights, all the catching equipment must have connections for extendable poles. In this way, bats can also be capture in roosts which are in heights of up to 10 m. As the extendable poles have a limited weight-capacity, the frame of some of the trapping equipment was made of aluminium. This material is less stable; which is why additional dip nets made of angled high-grade steel brackets (with padded edges) were used. Nevertheless, it was almost impossible to use them at heights of more than 7 meters. Additionally, the wind impact at heights of 8 to 10 meters puts the equipment under great strain, so that its wind sensitivity must be reduced. This can be done for example by using narrowly spanned threads instead of plastic film.

Figure 5:
Trapping at a 10 m high emergence gap of a common pipistrelle maternity roost, behind slate shingle panelling.

Funnel traps and dip nets make use of the principle that bats let themselves fall out of the emergence gap when leaving the roost. Thus they fall directly into the trapping equipment which is positioned in front of the emergence hole. The two types of trapping equipment can be distinguished in terms of the way they work: funnel traps have an opening at the front and are put in front of the emergence hole. This way, animals that lose only little height also can be captured. This type has turned out to be useful especially for vertical gaps. Dip nets have an opening on the upper side, and are rested against a place just below the emergence hole.

Bat species differ in the ease with which they can be captured. While **common pipistrelles** can be captured very easily with plastic dip nets, **serotine bats** react in a very sensitive way to rustling films. They feel disturbed by such noises and only leave their roosts with delay or not at all. Bat species like the **whiskered bat** or **Natterer's bat** are very agile when flying, and thus able to escape from voluminous funnel traps or dip nets. That is why the diameter of the catching equipment's opening should not exceed half a meter.

The catching equipment was generally removed after about half an hour to one hour. The animals were retained in plastic boxes, lined with a cotton bag with film border (as climbing barrier). Some funnel traps with a long cotton hose were employed, which made it possible for the animals to go directly into the retaining box.

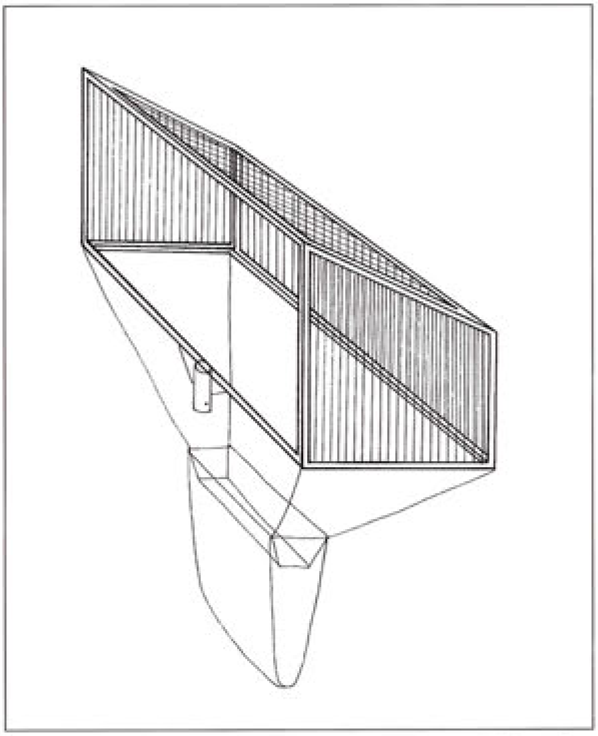

Figure 6: Basic type of dip net, spanned with fishing line. Below the metal frame is a plastic lining and fixed to this a cotton bag with a plastic cuff.

Banding

An individual identification of the captured bats was made possible with aluminium arm clips, which were numbered consecutively. These arm clips, often termed "rings", were supplied by the bat banding centre at the Koenig Museum in Bonn. For **common pipistrelles**, clips of the sizes "H" and "M" with a diameter of 2.9 mm can be used. **Greater mouse-eared bats** and **serotine bats** were banded with "X"-clips, which have a diameter of 5.2 mm. Neither injured bats nor underweight bats were banded. The arm clips are put on the bat‘s forearm and the ends are pressed together above the wing membrane. Between wing membrane and clip, a gap of about 1 mm is left open, so that the mobility of the clip fixed to the forearm is assured. When doing so, the gap may not be too big, otherwise the arm clip could slip over the elbow or the fingers could be trapped within the arm clip when the wings are folded close to the body. The ends of the arm clips are bent slightly outwards, so that they do not leave a sharp edge lying on the wing membrane. The arm clips were pre-bent with a metal rod of a corresponding diameter to assure that they kept their symmetry when pressed together.

Evaluation:

- high recapture rates can be reached within targeted banding projects (up to 90.5 %); average recapture rate at summer roosts of the common pipistrelle 35.2 % (compare chapter 4).
- Capture and banding of bats led neither to more roost switchings, nor to expulsions from the roost.

- All three bat species that were banded (common pipistrelle, serotine bat, greater mouse-eared bat) present a very low injury rate (< 1 %), due to the method employed. Quality control and pre-treatment of arm clips is essential for the minimalization of injuries.

3.1.4 Data compilation of captured bats

Aims:

- Evaluation of recaptures (e. g. roost switching, roost fidelity, limits of roost compound, spatial correlations between hibernaculum and summer roost etc.; compare chapter 7)
- Composition of a maternity roost (proportion of subadult females, males, young)
- Determination of a colony's reproductivity
- Individual weight development
- Relation between sexes amongst the young

Material:

- Set of scales

Procedure:

The following parameters of the captured bats were determined:

- Clip number of banded bats
- Sex
- Reproduction status (state of nipples or testes and epididymis, modified according to RACEY 1974):

  The state of the female's nipples is evaluated as follows:

  "A"= minimally developed, with hairs corresponding to the fur's colour; a sign for the fact that it has not suckled before.

  "B"= moderately developed, with a bare area surrounding the nipple; mostly with short, light hairs; the bat has suckled already.

  "C"= well developed, with a big bare area surrounding the nipple, a sign for being in the period of lactation.

For the males, the development of the testes was registered within two categories:

  "+"= the testes are enlarged

  "–"= the testes are not enlarged

  The epididymis were classified as follows:

  "–1"= black pigmentation (only valid for *P. pipistrellus*)

  "0"= not enlarged

  "+1"= filled and enlarged

  The category "–1" signals that the bat has not reached sexual maturity. After the epididymis has swollen up, the black pigmentation bands are macroscopically not visible anymore. Due to the swelling up of the testicles, the tissue expands so much, that a separation of the melanocytes takes place. This separation generally continues even after a discharge of the epididymis, so that the black pigmentation is a relatively reliable indication of sexual immaturity in males (RACEY 1974).

- Degree of ossification of the epiphyseal plates. The endings of the vertebrate's hollow bone are called pineal glands. The finger joints of juveniles are tapered and the epiphyseal plates are visible with the aid of a flashlight illuminating the wing (JUNQUEIERA & CARNEIRO 1986, RACEY 1974, SCHOBER & GRIMMBERGER 1998).

  0 = nobby and opaque, adult

1 = tapered and epiphyseal plates are visible, juvenile

- Weight
- Injuries, also ones already healed

Evaluation:

- For population ecological analyses age specific differentiation is of importance. To this aim, methods should be employed that are sufficiently comprehensible and objective. Age classification according to for colour f.e. is an inadequate method.
- An exact evaluation of the degree of ossification of the epiphyseal plates of the young can take place a maximum two and a half months after birth, and thus constitutes a reliable characteristic for the distinction between adults and young.
- The distinction between subadult females, that is, those that have never suckled (nipple-category "A") and adults, those that have suckled at least once (nipple-category "B"), is especially difficult to make with common pipistrelles late in the pregnancy in spring. During this period, the nipples of all females swell up, so that some females known to be subadult are classified as adults (nipple-category "B").

3.1.5 Radio-tracking

Aims:

- Detection of roosts
- Proof of roost switching
- Observation of use of roosts (also at night)
- Detection of hunting grounds
- Determination of home range
- Determination of flying routes
- Proof of spatial correlation between summer roosts and the swarming at mass hibercula during one night (long distance radio-tracking; see chapter 6.3)

Material:

- mini transmitter, between 0.46 and 1.5 g with battery life of 10 days to 9 weeks, range from 100 m to 6 km depending on the terrain
- mini transmitter with special functions (position transmitter, temperature transmitter)
- skin bond cement, plastic collar
- telemetry receiver, H antenna
- compass
- ultrasound detector
- topographical maps and road atlas
- 2-way radios

Procedure:

The radio-tracking was mainly useful to investigate the behaviour of roost switching or of roost compound respectively. Furthermore, the spatial correlation between summer roosts and hibernacula during the summer months could be ascertained by radio-tracking of single common pipistrelles (see chapter 7.5.1). The **common pipistrelle**, **serotine bat** and **greater mouse-eared bat** were examined telemetrically. The radio-tracking of other species like the barbastelle bat, whiskered bat and grey long-eared bat, was carried out less intensely, or sporadically. The selection of the transmitters depended on the respective weight of the bat.

According to the literature, the weight of the transmitter should not exceed 10 % of the body's weight (compare KALLASCH 1994). For the big bat species (**serotine bat** and **greater mouse-eared bat**), transmitters of about 0.8 to 1.5 g with a battery duration of three to nine weeks were employed. For the other, smaller species, transmitters of up to 0.5 g and a duration of 10 to 21 days were used. They were attached to the upper mid back, between the animal's shoulder blades, so that a least possible influence could be supposed. Some of the serotine bats were equipped with collar-transmitters to check the usefulness of an additional fixing method. Especially for greater mouse-eared bats, the use of a position transmitter turned out to be of great advantage. These transmitters change the distances between the different signals, according to the bat's position (whether vertical or horizontal). By judging by the different signal frequences, it could be ascertained whether the bats were flying or for example hanging in a tree hollow, as can be observed frequently with the greater mouse-eared bat.

The transmitters, in the worst cases, did not last longer than one night in the bat's fur. The longest period of time was 18 days. A reuse of the transmitters was mostly not possible, as they often fell off in inaccessible roosts (especially a problem at crevice roosts or tree hollows).

At the beginning of each unit of radio-tracking, generally two teams were formed, each consisting of two people with a car. Communication among the teams was assured by 2-way radio. The teams were positioned at advantageous places determined by the topography and infrastructure of the investigation area. These places apt for telemetry are highly exposed, in range of the signal and have access to a road. Two teams can determine the whereabouts of the bats, using cross bearings, and thus follow the quick movement of the bats. Due to the difficult terrain and the bat's high mobility, three teams were employed regularly during the first three nights to follow the greater mouse-eared bat. Once the bat's hunting grounds were known, one team was generally sufficient to pursue the animals.

The exact hunting grounds were generally located by cross bearings, and mapped.

The following specific questions were treated:

- Radio-tracking the whiskered bat tested the hypothesis that the animal orientates itself to landscape structures on its way to the hunting grounds.
- To carry out the so-called long distance radio-tracking, common pipistrelles, that had been captured and banded with an arm-clip before at a maternity roost in the district while swarming, were equipped with a transmitter (see chapter 6.3.9). Four telemetry teams were formed, one of which pursued the bat directly. The other teams were positioned on higher places of terrain, which lay in a bee-line between mass hibernaculum and the village where the bat had been banded before. Depending on the landscape structure, one telemetry team covered the area of potential connecting lines (e. g. Lahn valley) between hibernaculum and possible destination. Acccording to need, these teams also participated in the direct pursuit of the bat (see chapter 6.3).

Evaluation:

- The transmitters should be fixed with skin glue, rather than with a collar, as only this method assures that the transmitters fall off again within a few weeks. Nonetheless, transmitters that are glued to the animal can fall off after only a few days, which is a problem. Especially transmitters glued to crevice inhabiting bats get often lost in their inaccessible roosts.
- Because the glueing method only allows short units of radio-telemetry per animal, many bats in one colony must be attached with transmitters to establish that colony's hunting grounds and habitat requirements.

- The use of collar-transmitters with predetermined breaking point is advisable only for specific long-term studies. Even so, collars are not apt for all bat species. The biggest problem consists in the fact that the transmitters have to be removed again, as a predetermined breaking point cannot be relied on. While greater mouse-eared bats mostly hang freely in the roost and thus are relatively easy to catch, the catching of serotine bats, equipped with transmitters, has turned out to be extremely difficult. Serotine bats learn very fast; they realize when nets or funnel traps are put up in front of the roost, and avoid them! Therefore collars are not suitable for serotine bats, for example.
- Radio-tracking is very successful for the specific determination of hunting habitats of all bat species equipped with transmitters. Though the animals could not always be pursued uninterruptedly, it was still possible to radio-track them for the major part of the night. Especially highly mobile species, like the serotine bat and the greater mouse-eared bat easily get out of the receptor's range as they change hunting grounds.
- Telemetry makes it partly possible to observe the pursued bats directly within the hunting area.
- Potential disturbance from the transmitters could not be detected in those bats equipped with transmitters.
- Telemetry is difficult to carry out in the forest, due to the low range of the transmitters (some 100 m only).
- The high personnel expense can increase with the very mobile species. For the greater mouse-eared bat, for example, often at least two teams have to be employed.

3.1.6 Nocturnal observations of behaviour at the roost

Aims:

- Nocturnal activity at the roost
- Nocturnal use of roosts
- Roost switching
- Reconnoitre of roosts

Material:

- Ultrasound detector
- Night vision glasses
- Video camera with infrared light

Procedure:

In order to obtain detailed information on the nocturnal activity at roosts, and roost switching behaviour in particular (see chapter 7.2), the maternity roosts of the common pipistrelle and the serotine bat were observed systematically during the whole night.

Eight rounds of 45 minutes each were carried out every night in a village with numerous maternity roosts of the common pipistrelle. Five maternity roosts lay along the route of each round. During the inspections, the bats' activities were recorded at every roost for five minutes. Thus, the total period of observation was 40 min per night at each roost. In addition, the flying activities at two other roosts were recorded with a video camera (infrared light).

For the investigation on the nightly activity of the serotine bat, a building complex was chosen with a total 123 wall crevices altogether (5–15 cm high, 1 m wide) on three sides (east, south, and west exposure) above the windows. These are already known and potential roosts. Observations over a whole night were carried out by three people at once at this location.

The observations started about half an hour before sunset, and endured until the end of dawn the next morning. When bat activity was detected, red-light floodlights were used to shine on the relevant part of the building, and the behaviour (overflight, approach, entering the roost, emerging from the roost, swarming) was written down or spoken onto a dictation machine. The use of night vision glasses was very helpful here.

Evaluation:

- Rounds encompassing various roosts are only partly apt for species like the common pipistrelle, which changes its roost frequently and uses up to 16 roosts in the course of one maternity period (compare chapter 7.2.1). A correspondingly high number of roosts would have to be observed in parallel.
- Observations during a whole night at a roost complex, like the one of the serotine bat, are adequate to observe exactly the behaviour of the bats during nights of roost switching (compare chapter 7.2.2).
- Application of automatic video observation systems is limited for watching roost complexes.
- All methods require much time and personnel.

3.1.7 Use of chemiluminescent light sticks

Aims:

- Direct observation of various individuals at the same time
- Investigation of flying behaviour (e. g. use of flying routes)
- Observation of specific use of foraging areas
- Further observations of behaviour like reconnoitre of mass hibernaculum

Material:

- Miniature chemiluminescent light sticks (synthetic) taken from fishing equipment (2PCS Mini, colours: yellow, red, blue; non-toxic; 2.3 cm long)
- Skin bond cement

Procedure:

The luminiscent miniature light sticks were glued to the animal's back. The least possible glue was used for this, to assure that the sticks fall off quickly. To determine the use of foraging areas or of flying routes, 10 animals in each case (common pipistrelles from two villages, serotine bats from one village) were banded on one evening with the light sticks. At least 10 people were positioned at potential flying routes or known hunting grounds of the colony.

For the investigation of the reconnoitre behaviour of the common pipistrelle at mass hibernacula, adult females, adult males and young were equipped partly in parallel with miniature light sticks of different colours. Their behaviour in the hibernaculum, as well as the time of leaving the roost, were at the centre of interest.

Evaluation:

- Miniature light sticks make it possible to observe bats very efficiently, while the expense is low.
- The miniature light sticks have proved worthwhile for common pipistrelles and serotine bats, for the determination of flying routes and exact hunting grounds, as well as

for the investigation of common pipistrelle reconnoitre behaviour in the mass hibernaculum (see chapter 11.3 and chapter 6.2.3). When only one colour is used, yellow is the most advisable, as red and blue shine less strongly and are seen over much shorter distances.

3.1.8 Automatic roost surveillance

Automatic roost surveillance was carried out with ultrasound sensors, photo-electric beam light barriers, and video surveillance with infrared lighting.

Aims:
- Determination of colony size
- Observation of roost switching, searching and reconnoitre behaviour, and activity at the roost
- Determination of time of flying in and out
- Checking of method (light barrier / ultrasound sensor and video camera)

Material:
- Ultrasound sensors
- light barrier with 4 double rays
- datalogger
- Video camera black and white
- charge-coupled device camera
- VHS long-term recorder (with 24 hours of recording time and time slot in)
- screen
- Infrared constant light or stroboscope floodlights

Procedure:

Light barriers were primarily installed at roosts which only had one possibility for the bats to fly in or out. In addition, the distance of the transmitting and receiving diodes has to be between 5 cm and 80 cm, and the emergence gap must not be wider than about 8 cm. The light barriers were connected to a datalogger (storage of 129,000 time-coded data sets), which at the same time had connecting possibilities for two ultrasound sensors, one external temperature sensor and one humidity sensor. The equipment can be run from net current or batteries. Light barriers were used at the roosts of **common pipistrelles, serotine bats** and **greater mouse-eared bats.**

Video surveillance can be employed at almost all roosts. Depending on the question the surveillance is to answer, there is the possibility of adjusting recording speeds on the video recorder (time modi: real time, 6 h mode, 12 h mode and 24 h mode). While the time of flying out was recorded in real time, for example, the complete night observations at roosts were generally carried out in time-lapse (6 h mode, or 12 h mode). The recording mode of the video recorder can be controlled additionally by ultrasound sensors (when there is a flying or ultrasound activity, the recording speed switches from time-lapsed to real time modus). Video surveillance with infrared floodlights was installed to observe the roosts of **common pipistrelle, greater mouse-eared** and **serotine bats**. Additionally, the functionality of light barriers was checked, using video recordings.

Ultrasound sensors record the relative activity of echolocation calls of the bats. They generally were installed parallely to the other observation units, in order to control the video observation or check the method. In addition, the systematic arrangement of ultrasound sensors was useful for the investigation of search and monitoring behaviour of the **common pipistrelle** (compare chapter 6.6).

Evaluation

- Longer databases can only be gained at chosen roosts, which are used with a relative continuity. Thus, the employment of a light barrier at a frequently used serotine bat roost, has turned out to be as adequate as the light barrier at the entrance and emergence opening of a common pipistrelle's mass hibernaculum. Using three installed light barriers at a maternity roost of greater mouse-eared bats, patterns of nightly activity could be recorded successfully.
- During the employment of automatic roost observation, no spoilage of the animals could be detected.
- The mobile video observation was especially useful at roosts of the common pipistrelle, as it can be put up and removed again very fast.
- The different observation methods partly completed each other well or were useful for mutual checking. Thus, the functionality of the light barriers could be checked by video camera.
- The use of automatic observation systems turned out to require a very intensive care. The functionality of these systems need to be checked especially at the beginning of the period of validity, leaving only small periods of time in between. Nevertheless, the checking must be carried out continously as well, in order to get reliable data. Otherwise, numerous data gaps can partly turn up.
- Bat species that change their roosts frequently, are almost impossible to investigate by automatic observation systems. The common pipistrelle uses up to 16 maternity roosts a year, while up to 29 maternity roosts of one colony have been detected within the period of 3 years, in one place.
- Light barriers are only adequate for small emergence gaps, due to their limited range between transmitter and receiver diode.

3.1.9 Temperature measurement in roosts

Aims:

- Determination of the temperature regime in bat roosts
- Investigations of the factor temperature in relation to roost switching

Material:

- Temperature sensors, connected to datalogger

Procedure:

To measure the temperature, a temperature logger was used, to which a maximum 15 temperature sensors can be connected. Efforts were made to errect the sensors at the bats' hanging places or at least near them, so that the real roost temperature could be determined. The recorded data were read via computer.

Evaluation:

- The rough spectrum of the roost temperature can be well determined with temperature sensors.

- It is generally very difficult to take the temperature in crevice roosts. In most cases, only the emergence opening of the roost is visible (and accessible), and the changing hanging places of the bats can only seldomly be located.
- The interpretation of temperature data is difficult due to the bats' thermo-regulatory adaptibility, which makes it possible for them to fall into a torpor, or else to keep a higher body temperature (social thermo-regulation).

3.1.10 Genetic Investigations of bats

Mitochondrial sequences were used as genetic marker to investigate the relationship within and among pipistrelle nursery colonies.

Aim:
- Determination of genetic composition of a colony
- Evaluation of females' fidelity to place of birth (natal philopatry)
- Estimation of the exchange of individuals between colonies

Material:
- Biopsy punch to extract skin samples
- Alcohol to disinfect the biopsy punch and to store the skin samples
- Laboratory methods see chapter 8

Procedure:

The bats were captured at maternity roosts, and the tissue was taken and placed in alcohol. The samples were frozen at –20 °C until further processing. No samples were taken from bats that already had holes in their wing membranes, e. g. caused by mites or injuries at the roost.

Evaluation:
- Non-lethal method to get samples for a genetic study
- Samples can also be taken from dead animals (though degenerated DNA may cause problems).
- Allows statements about genetic composition and the genetic exchange among populations (here maternity roosts).
- Time consuming and expensive lab work.

3.1.11 Use of Geographical Information Systems (GIS) to analyse the habitat of different bat species

Aims:
- Description and analysis of foraging areas, using known structure parameters
- Analysis of the habitat of one colony, using ecological landscape parameters

Material:
- Data of occurrence and spacing of bats
- Digital topographic maps (scale 1 : 25.000)
- Digital "Ortho-photos" (ground resolution: 2 m)
- Computer program ArcView® Version 3.1 (ESRI Inc., Redlands, California, USA)

Procedure:

Depending on the database, structures of known foraging sites can be determined and quantified by means of aerial photos and topographic maps. The data gained here can be compared with randomly chosen areas, so that it is possible to determine whether foraging areas of one species or population have a species-specific character. If the foraging sites are not known, the potential habitats (summer homeranges) of colonies can be compared with each other and compared with areas in which these bats do not occur.

Evaluation:

- The GIS-supported habitat analysis makes it possible to identify habitat requirements of bats.
- A good to very good knowledge of the occurrence and the foraging sites of the species is necessary. A detailed pre-investigation into the terrain is an important prerequisite in gaining this information.

3.2 Balancing of expense of the recording methods

Of the 585 bat roosts found in the Marburg-Biedenkopf district since commencement of the project, more than half (336 roosts) were recorded via detector mapping (see figure 7).

Private people reported 150 additional roosts. These reports of roosts are largely due to public relations work, which was essential for roost recording, especially during the first year of investigation (1997: 41 % of the summer roosts) (see figure 8). The number of reported findings decreased steadily in the years thereafter (2000: 12 % of summer roosts). Roosts reported by honorary environmentalists were also mostly reported at the beginning of the project. An accurate, systematic and quantitative roost recording can only occur via direct recording of the bats, that is, via mapping and telemetry.

Success and effectiveness of recording the bats and their roosts

The effectiveness of mapping in settlements depends on numerous factors, such as the density of buildings, the method of construction and building structures. Since it would be almost impossible to quantify all these factors, the following simplified picture emerges:

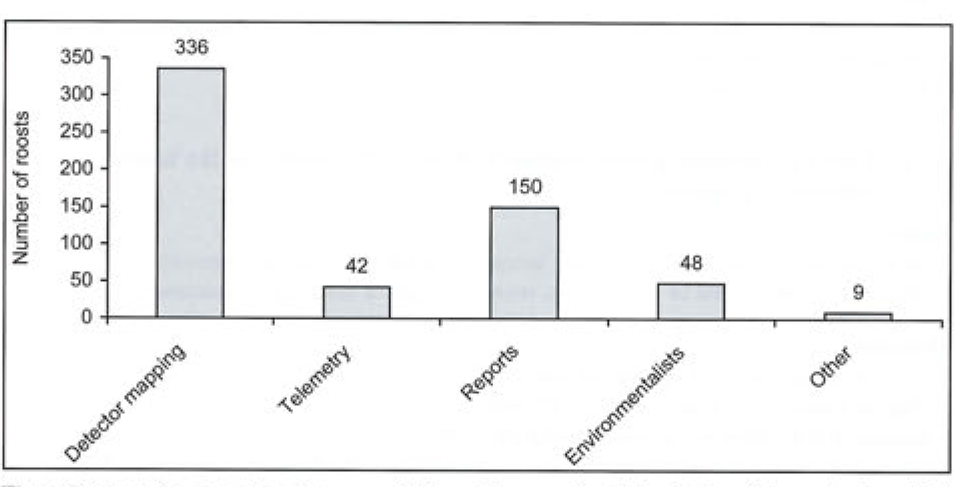

Figure 7: Recording methods and sources of all roosts known since the beginning of the project (n = 585).

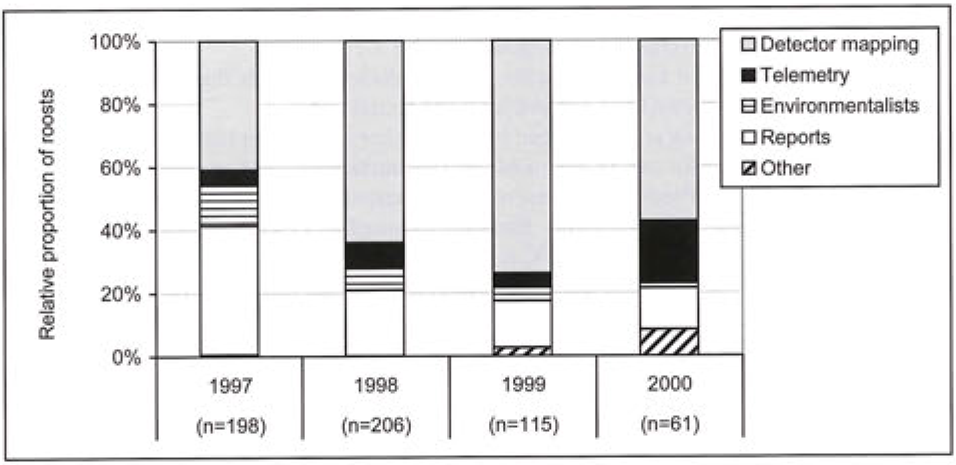

Figure 8: Relative proportion of each recording method and source of all roosts during the years 1997 to 2000.

The number of bat roosts recorded via mapping depends directly on the number of the inspections made on foot per village in the evening and in the morning (see figure 9). With an increasing number of mappings per village the number of bat roosts found also increased. At least three mappings per village were necessary to guarantee the discovery of a bat roost. Sometimes no roost could be detected in villages where only one or two inspections were carried out. On average, however, one inspection was sufficient to detect two roosts. As maximum value, 46 roosts were found during 70 inspections in one village (about 2,000 inhabitants) over 4 years. This number of roosts reflects the roost switching behaviour of the

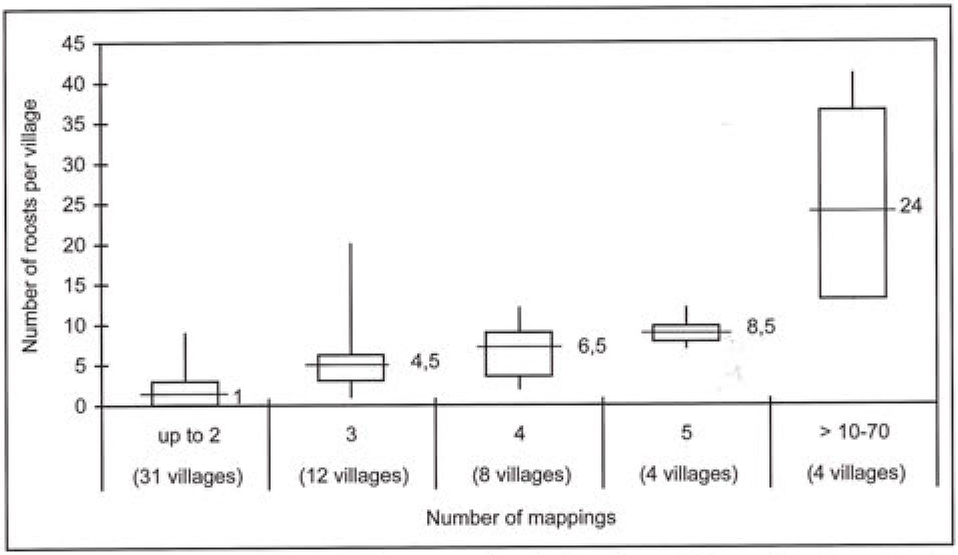

Figure 9: Number of roosts found via detector mapping, in dependence of the number of mappings per village.

different bat species. One colony will use a great number of different roosts in one village within a year and over several years (compare chapter 7.2).

The rectangles mark 1st and 3rd quartile, the perpendicular bands the complete range of values. The median is marked and entered by a horizontal line.

If the success of mapping is to be judged on the number of different bat species found, then it is noticeable that hardly any or no roosts of the **barbastelle bat** or **Natterer's bat** are reported (see figure 10). Proof of the presence of barbastelle bats in Hesse is limited to a few winter discoveries over the last decades. Summer roosts of this species have not been known in Hesse for more than 40 years (KOCK & ALTMANN 1994). Maternity roosts of the barbastelle bat are not yet known at all. **Long-eared bats** often roost in attics or hunt there. Excrement or single individuals are therefore found more often by chance than in the case of the Natterer's bat, and for this reason also reported more often. As Natterer's bats call louder than long-eared bats, they are easier to map. Moreover, they can often be found in cowsheds hunting, so that it is generally easy to prove the presence of this species in a village, and thus a further, targeted search for the roost is often successful. That is why most of the known roosts of the Natterer's bat are found via mapping; the percentage of reports is very low.

Maternity roosts of five bat species could be recorded by telemetry (see figure 11). This method especially helped to locate the individual roosts of **serotine bats** and **common pipistrelles**, which are otherwise difficult to find. Mapping finds individual roosts only by chance, as swarming behaviour there is not intense, is of short duration or not present at all. Reports of individual roosts are also rare. It is usually only possible to find them via telemetry. Night roosts are exclusively recordable using telemetry.

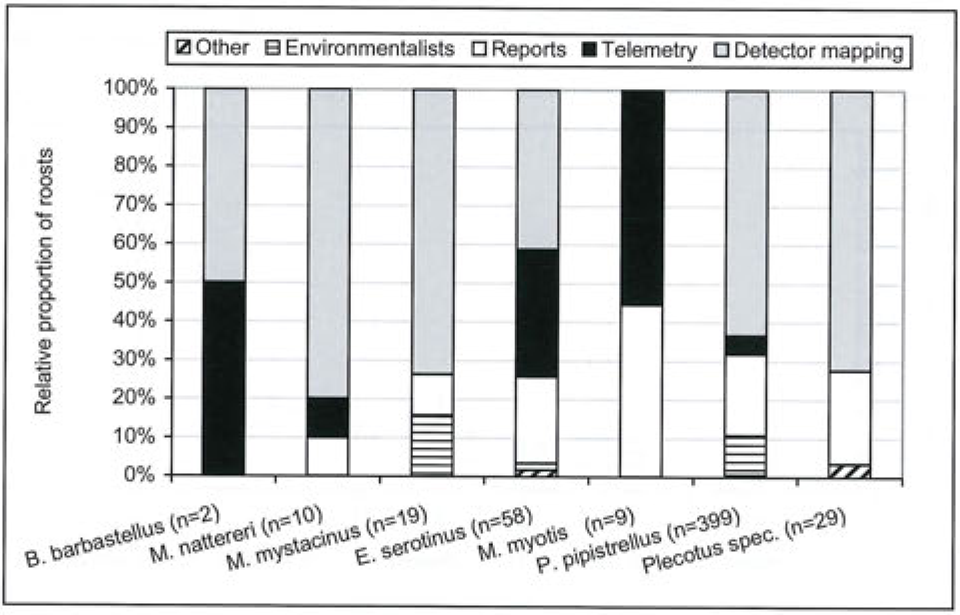

Figure10: Relative proportion of recording method or sources of roosts, divided according to bat species (n = 530). The roosts where the species could not be determined with certainty (n = 58) were not taken into account.

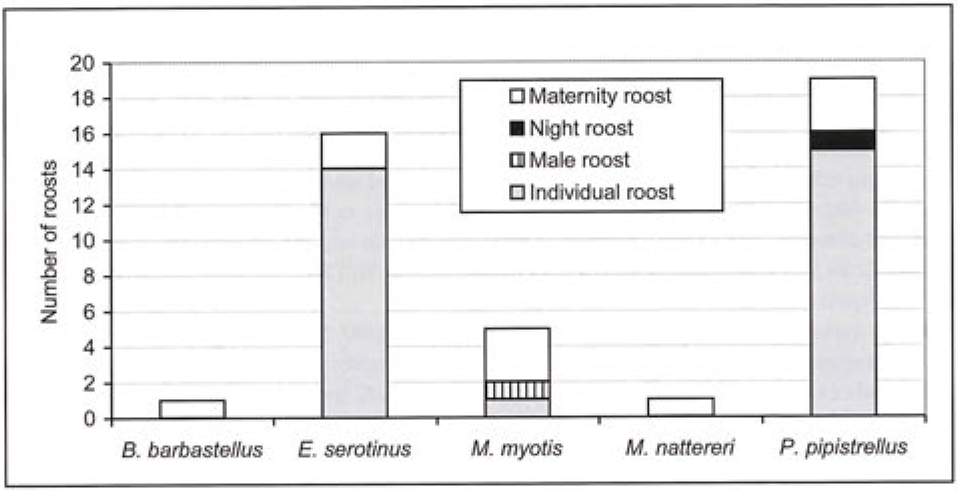

Figure 11: Number of roosts of the different bat species that have been detected via telemetry (n = 42).

Total expense of bat recording

During the years 1997 to 2001, a total 13,432 hours (corresponds to 1,679 working days, of 8 h each) were employed to record data of bats (see table 2). The public relations work, from which many roost reports resulted indirectly, especially in the first year of investigations, is not considered here, as its expense was not possible to balance. The most time intensive method was telemetry. The main reason for this is that both roost switching and the nocturnal activity of the bats were investigated by means of this method.

Table 2: Recording methods of bat data during the years 1997–2001 and the respective expense in working days.

Method	Labour time [h]
Emergence observation	1,218
Acoustic detection	2,075
Radio-telemtry	8,184
Capture	1,400
Observation the whole night	555
total	13,432

4 State of the registration of bat population numbers before and after the project

A fundamental prerequisite to understanding insights gained in the project is to explain the present state of the registration of house-dwelling bats in the project area and the related investigation effort. This chapter therefore is dedicated to the results of bat stock-taking in this for the most part rural area of more than 1,200 square kilometres containing over 170 towns and villages. In accordance with the feasibility and aims of the investigation, three typical and widespread species of house-dwelling bats were in the foreground of the investigation: the common pipistrelle, the greater mouse-eared bat and the serotine bat. Less frequent and difficult to record species such as the whiskered bat and the grey long-eared were to play a less important role.

In the framework of the project, mainly from 1997 to 2000, 543 new registrations were made of bat summer roosts in buildings. These consist of 331 maternity roosts, 197 individual roosts and 15 other summer roosts (compare table 3) of 12 different species of bats. Two further species could only be discovered in winter on facades of buildings (noctule bat, party-coloured bat). Therefore it can be assumed that nearly all local species in the investigated area – with the exception of the Daubenton's bat – use above-ground housing as roosts. As was to be expected, the common pipistrelle dominates. Many roosts of the serotine bat could also be found. Significantly less roosts of other species were recorded, which is also related to the difficulty of locating them. Some species, for example Bechstein's bat and Leisler's bat, can usually only be found on buildings in exceptional cases, whereas the colony of Leisler's bats in Marburg has been observed annually in the same known creviced buildings over the last 10 years.

In spite of the apparent discrepancy between the number of proven roosts and colonies of the common pipistrelle (in 80 locations) and the other species, the proven existence of 17 maternity roosts and 14 colonies of the whiskered bat in the project area represent a significant number when compared to other regions (see next chapter).

The banding of bats not only provides knowledge about the number and status of summer roosts in the investigated villages, but is also important in answering questions of population ecology. Before the project, the "ringing" of bats in the Marburg-Biedenkopf district took place only sporadically and predominantly unsystematically. Neither data nor results of this "ringing" has been published so far.

At the beginning of the investigation the common pipistrelle, the serotine bat and the greater mouse-eared bat were banded. 27,471 captures of bats with 20,382 bandings could be made of these three species during the project (see table 4). On the basis of the individualisation of these bats and the numerous, targeted recaptures, much information could be gained about the population ecology and spatio-functional aspects of bats (see next chapter, and chapters 6 and 7).

The first systematic banding in the district began in 1996 in the mass hibernaculum of the common pipistrelle (45 kHz) in the cellar of Marburg Castle (compare SENDOR & SIMON 2000). These investigations were continued and enlarged in the project. In this way the common pipistrelle became, with 24,884 captures of 18,957 individuals (= banding) and 5,927 recaptures, the most frequently captured and banded bat at that time in Europe.

The first captures and the recaptures of the greater mouse-eared bat nearly counterbalanced each other, but the number of recaptures increased clearly over the course of the investigation and in 2000 exceeded the number of the first captures (see figure 12).

1,113 bats of another 12 species were captured without banding (compare table 5). The aims of these captures were diverse: determining the species, proof of reproduction, telemetry, taking of skin samples and so on (compare chapter 3).

Table 3: All records of bat presence over summer in the project area (Marburg-Biedenkopf district), making distinctions according to the species and "before the project" and "during the project". * Summer records not for all species.

		Maternity roost	Individual roost	Proof of reproduction	Summer roost	Summer proof*	Tree roost (> 1 bat)	Tree roost	"Zero village"(s. 11.2.3)	Total "during project"	Total "before project"	Total
Pipistrellus pipistrellus	project	253	149							402		
	before project	34	5								39	
	total	287	154									441
Eptesicus serotinus	project	30	28		2	15				75		
	before project	7	4			1					12	
	total	37	32		2	13						84
Myotis nattereri	project	11		2		24			41	37		37
Myotis mystacinus	project	18	6			3				27		
	before project	3	1								4	
	total	21	7			3						31
Myotis myotis	project	1	9		2	5	2	6		25		
	before project	3									3	
	total	4	9		2	5	2	6				28
Plecotus auritus	project	8			4	8				20		
	before project	2			1						3	
	total	10			5	8						23
Plecotus austriacus	project	7	1		2	3				13		
	before project	4			4						8	
	total	11	1		6	3						21
Plecotus spec.	project		3		4	3				10		
	before project	1	1								2	
	total	1	4		4	3						12
Barbastella barbastellus	project	2				2				4		4
Myotis bechsteinii	project			1		1				2		2
Nyctalus leisleri	project	1								1		
	before project	1									1	
	total	2										2
Pipistrellus nathusii	project		1							1		1
Myotis brandtii	project				1	1				2		2
Total		331	197	3	15	65	2	6	41	619	72	688

Table 4: Overview of numbers of *Pipistrellus pipistrellus*, *Myotis myotis* and *Eptesicus serotinus* captured, banded and recaptured in the project.

Species	Site	Mark	Recapture	Total
P. pipistrellus	Summer roosts	3,950	1,391	5,341
	Foraging sites	8	13	21
	Invasion site	1,219	72	1,291
	Mass hibernacula	13,744	4,448	18,182
	Other hibernacula	36	3	39
	Total	18,957	5,927	24,874
M. myotis	Summer roosts	1,065	918	1,983
	Hibernacula	10	0	10
	Total	1,075	918	1,993
E. serotinus	Summer roosts	346	254	600
	Hibernaculum/Invasion site	4	0	4
	Total	350	254	604
Total		**20,382**	**7,099**	**27,471**

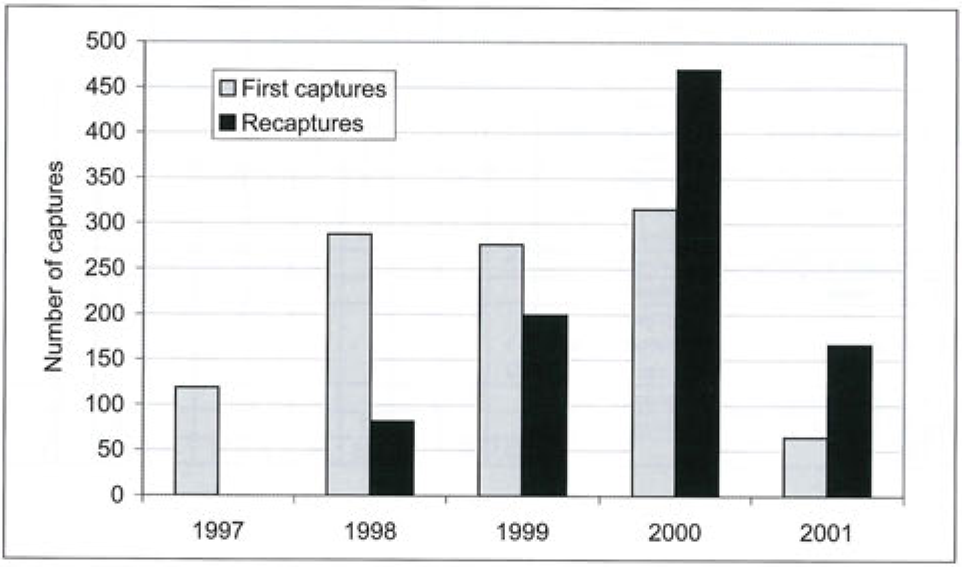

Figure 12: Number of first captures and recaptures of the greater mouse-eared bat over the course of the investigation.

Table 5: Overview of the number of bats of other species captured in the project but **not** banded.

Species	Locality of capture	Number of bats
M. mystacinus	summer roosts	75
	hibernacula	8
M. bechsteinii	hibernacula	5
M. daubentonii	hibernacula	7
	foraging sites	1
M. nattereri	summer roosts	21
	hibernacula	2
P. auritus	summer roosts	9
	hibernacula	16
P. austriacus	summer roosts	6
B. barbastellus	summer roosts	40
	hibernacula	4
	invasion site	1
N. leisleri	summer roosts	3
N. noctula	invasion site	1
V. murinus	hibernacula	1
P. nathusii	summer roosts	1
	hibernacula	1
P. pipistrellus	mass hibernacula outside project area	919
12 species	**total**	**1,113**

4.1 Common pipistrelle (*Pipistrellus pipistrellus* [Schreber, 1774]) – 45 kHz-type

4.1.1 Distribution and abundance within the project area

The common pipistrelle is, by far, the most often recorded bat species in Hesse. Common pipistrelles could be observed in every mapped village in the project area (observations of bats flying). Individual or maternity roosts – altogether 441 – were recorded in about 95 % of the villages and towns. No maternity roosts were recorded in only 5 (= 7 %) of 70 mapped villages. Altogether 253 new maternity roosts could be recorded. By means of intensive mapping in several villages, up to 27 maternity roosts of a particular colony could be discovered in one single village (compare figure13).

Less individual and male roosts (n = 149) than maternity roosts were found. The latter are more highly frequented and thus easier to locate. Only 20 individual roosts were located in 4 years in frequently mapped villages like Wittelsberg (see figure 14). This species does not appear to be distributed evenly over the whole project area. There are indications that it prefers villages near to aquatic habitats (compare chapter 11.2).

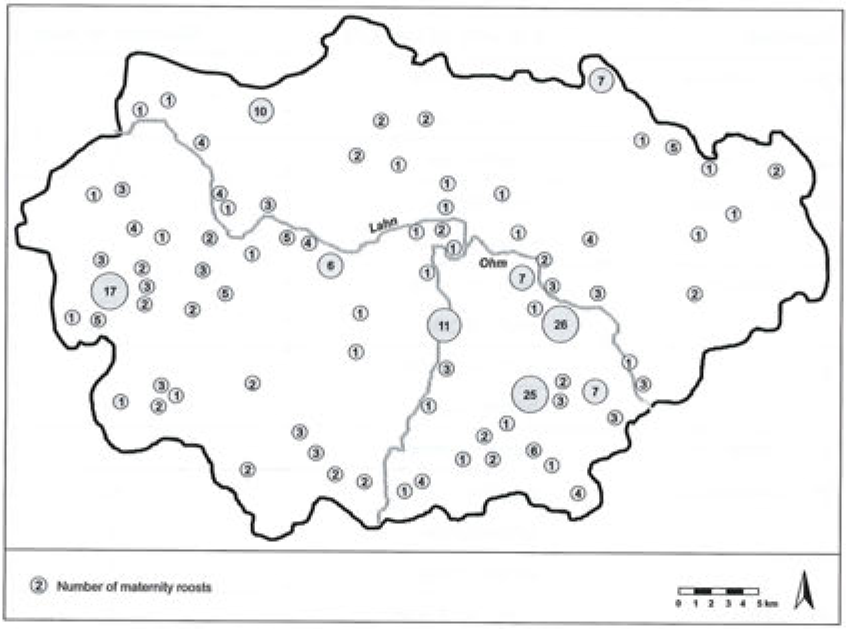

Figure13: Villages containing proven maternity roosts of the common pipistrelle (*Pipistrellus pipistrellus* 45 kHz) within the project area (n = 253).

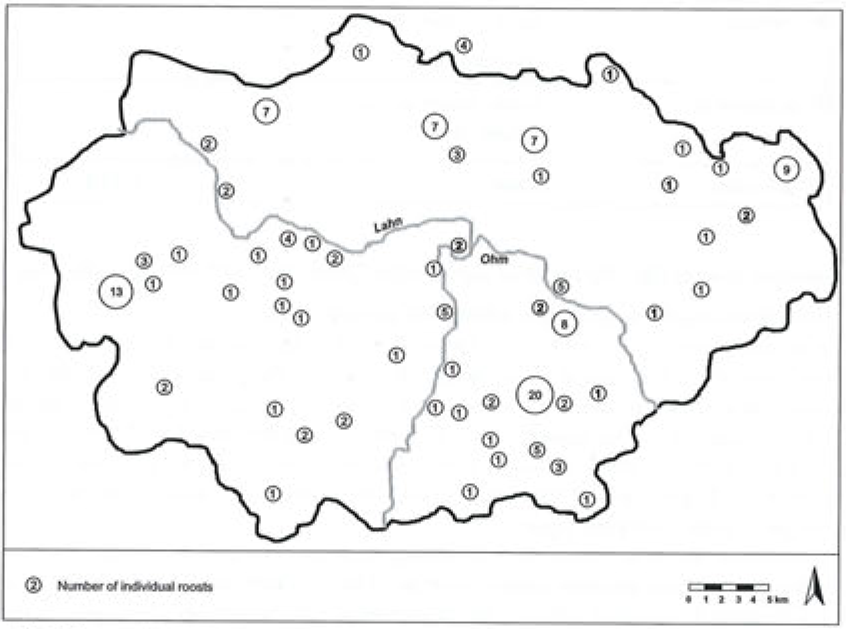

Figure 14: Villages with evidence of individual roosts of the common pipistrelle (*Pipistrellus pipistrellus* 45 kHz) within the project area (n = 149).

Estimation of common pipistrelle stocks

Size of a maternity colony

All data recorded on adult female common pipistrelles until October 1999 serve as the basis of this estimate. Juvenile common pipistrelles in their first year were not taken into consideration, because of the high mortality rate in that year (compare THOMPSON 1987, SENDOR & SIMON 2000). The average number of all adult females in one village was recorded as another basis of the calculation. Only villages were used, where a determination of the size of the colony was sufficiently ensured. Colonies where the count of several emergences and/or captures in one or several maternity roosts was not available, had to be disregarded. Therefore the colonies of 26 villages of the Marburg-Biedenkopf district were used, where between 45 and 185 adult female common pipistrelles could be recorded according to different methods. It follows from these facts that the average size of a maternity roost is about 88 (S.D. = 39) female common pipistrelles per village and colony. Usable results for comparison are rare in literature. The reason is that the common pipistrelle was largely regarded as one species up to the mid-1990's. Since then it was known that there were actually two cryptical species (compare BARRAT et al. 1997, JONES & VAN PARIJS 1993). Therefore there is only one value for comparison, by BARLOW & JONES (1999), where the two species, *P. pipistrellus* (45 kHz) and *P. pygmaeus* (55 kHz), are treated separately. They found out that the number of the 45 kHz type bats (median 76 animals, 33 roosts) per roost was evidently lower than the number of the 55 kHz type bats (median 203 animals, 40 roosts). Older statements concerning the size of colonies, as from THOMPSON (1990) are not comparable, because obviously both types (species) were investigated as one. The findings of SPEAKMAN et al. (1991) (18.2 *Pipistrellus pipistrellus* per km^2) also should be evaluated in this context. They found maternity roosts with more than 1,000 individuals (typical for the 55 kHz type) and also could not distinguish between the two different species of common pipistrelles.

GRIMMBERGER (1983) determined 64 adult females per maternity roost (n = 35) on average for eastern Germany. The problem of the differentiation between the "45 and 55 kHz – common pipistrelle" also existed for this area.

The statement of "88 female common pipistrelles per village in the project area" does not take into account that there is sometimes more than one maternity roost in large villages, whereas there is sometimes none in little or middle-sized villages (see chapter 7.2.1). The mapping results show that nearly 8 % of all the investigated villages had no maternity roosts (view chapter 4.1.1). Our investigations were able to show that even in larger villages, there can be more than one colony or that big colonies develop, which split up into smaller colonies (see chapter 7.2.1.1). A differentiation of the size was not made when investigating the number of villages. Because "larger villages" where one can expect to find more than one common pipistrelle colony make up approximately 10 % of total localites, the simplified calculation of one colony per village may be considered accurate enough.

Population density of common pipistrelles

The mass hibernaculum in Marburg Castle in Central Hesse can be regarded as an important "headquarter" of the common pipistrelle (see chapter 6.2.1). About 5,000 individuals winter there, and 20,000–30,000 animals reconnoitre this roost during the summer months (compare SIMON & KUGELSCHAFTER 1999, SENDOR & SIMON 2000). The spatial relationships between summer roosts and the hibernaculum could be ascertained from examining the armclips of banded common pipistrelles (see figure 16 and compare chapter 7.5). Common

Figure 15: View of Marburg Castle. Up to 5,000 common pipistrelles hibernate here in an above-ground cellar.

pipistrelles come from a radius of at least 40 km to spend the winter in the mass hibernaculum or to reconnoitre the roost during the summer months. These spatial relationships prove the special and central status of Marburg Castle as hibernaculum and summer swarming place (see chapter 6.2).

Deviding the project area into concentric rings around the mass hibernaculum (figure 17) – justified by the central role of the site – enables the verification of a population estimate based on "ringing" data. The surroundings of the castle were divided into rings of 5 km distance from the castle and then the number of towns and villages in each ring section was defined. The number of females could then be estimated for each ring area (see table 7). In a radius of 40 km around Marburg Castle containing 667 villages multiplied by an average of 88 females per colony per village, **58,696 female, adult common pipistrelles** can be calculated for this area. Therefore about 117,500 adult common pipistrelles (females and males, with a theoretical ratio of 1:1) and 180,000 adult and juvenile common pipistrelles (with one young per adult female) are estimated to be in a total area of 502,600 ha. This corresponds to a population density of 0.24 and 0.36 respectively per ha, or about 24 and 36 individuals respectively per km^2.

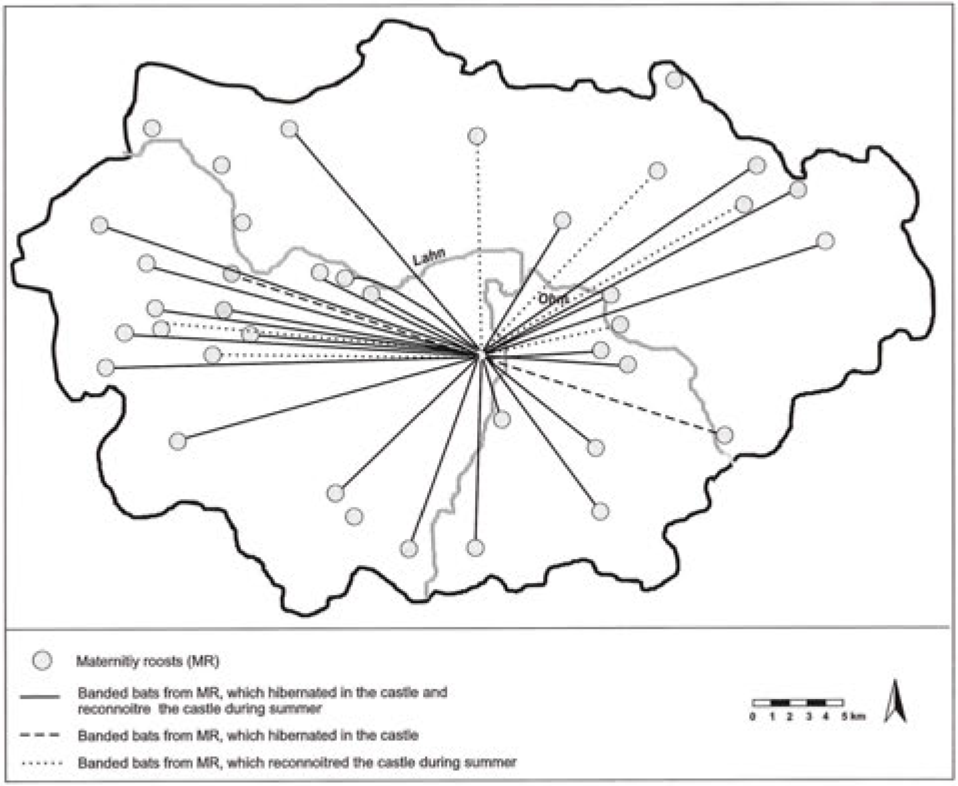

Figure 16: The spatial relationships of common pipistrelles in the project area, which could be ascertained from banding. The mass hibernaculum is situated in the centre of these relationships.

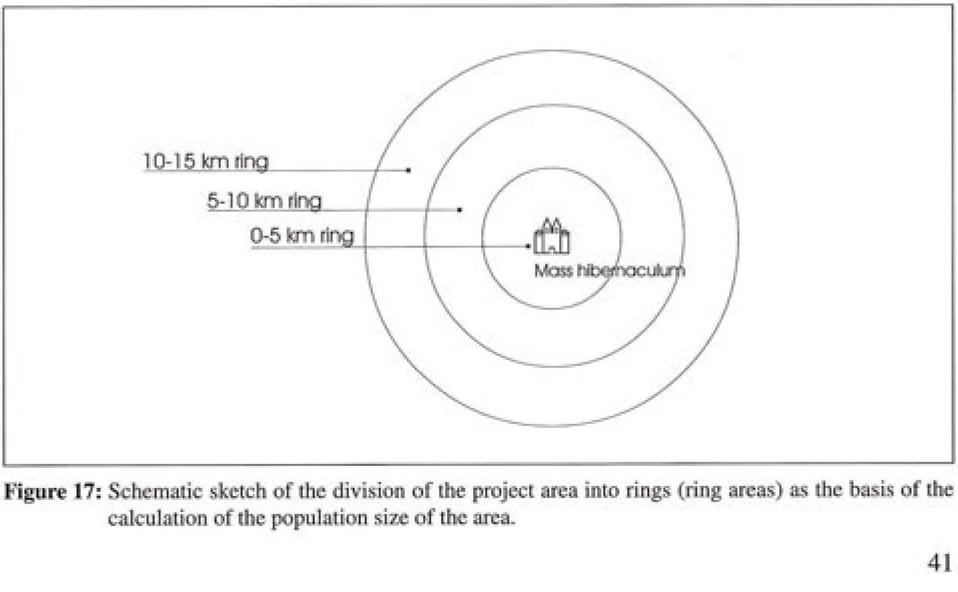

Figure 17: Schematic sketch of the division of the project area into rings (ring areas) as the basis of the calculation of the population size of the area.

Testing of the population estimate calculation

The plausibility of this calculation or population estimate can be tested by results of the simultaneous investigations at the hibernaculum and the maternity roosts. The link of the spatial and functional relationships between the maternity roosts and the mass hibernaculum can only be accurately assessed if the quantitative relationships are also sufficiently known. This means that a sufficient number of animals captured and banded in the hibernaculum had to be recaptured from the surrounding maternity roosts. The following calculations include only the recaptures of maternity roost females which were banded in the cellar of Marburg Castle.

To illustrate the connection between the hibernaculum and the summer roost, one can chart the common pipistrelles which were recaptured in maternity roosts away from the castle (n = 268), showing the distance from the castle. The further the maternity roost is situated from the hibernaculum, the lower is the exchange rate, that is the share of the recaptures decreases (see figure 18). This connection is all in all somewhat weak ($R^2 = 0.29$), and the mean variation is rather wide. 51 data sets with 268 village switches from 1997 to 1999 from 33 villages (see table 6) served as a basis. Here, some villages were included several times in different years. The regression curve, which sums up this connection, allows one to read the percentage of recaptured bats already banded or captured in the castle.

To test the estimation, the relative percentage of the common pipistrelles (banded at the castle) recaptured in each ring area around the mass hibernaculum was read from the regression curve. From this calculation arose the number of individuals per distance classification. These two values enable one to calculate the hypothetical number of bats that would have to be banded at Marburg Castle to reach a similar result. This means that at least 2,301 female common pipistrelles would have had to be banded in the castle in order to achieve 268 recaptures among the total 58,696 females (assuming that the spatial distribution corresponds to the regression). In fact, however, approximately 4,900 female, adult common pipistrelles were banded in the castle – that is to say, twice as many. The estimation of 58,700 bats is undoubtedly too low. According to the present results first projection must be readjusted to the order of 60,000–100,000 adult females within the radius of 40 km.

Table 6: Data underpinning the representation of the connection between recapture rate of adult, female common pipistrelles banded in the hibernaculum (Marburg Castle) and the distance from castle to maternity roosts.

A – number of villages and colonies, where bats were captured at maternity roosts.

B – captures of all adult females within one village and year.

C – recaptures of adult females which had been captured in the castle any time previously.

Year	1997	1998	1999	Total
A – Number of villages	13	22	16	33
B – Captures of females	1120	1386	922	3428
C - Recaptures	69	93	106	268

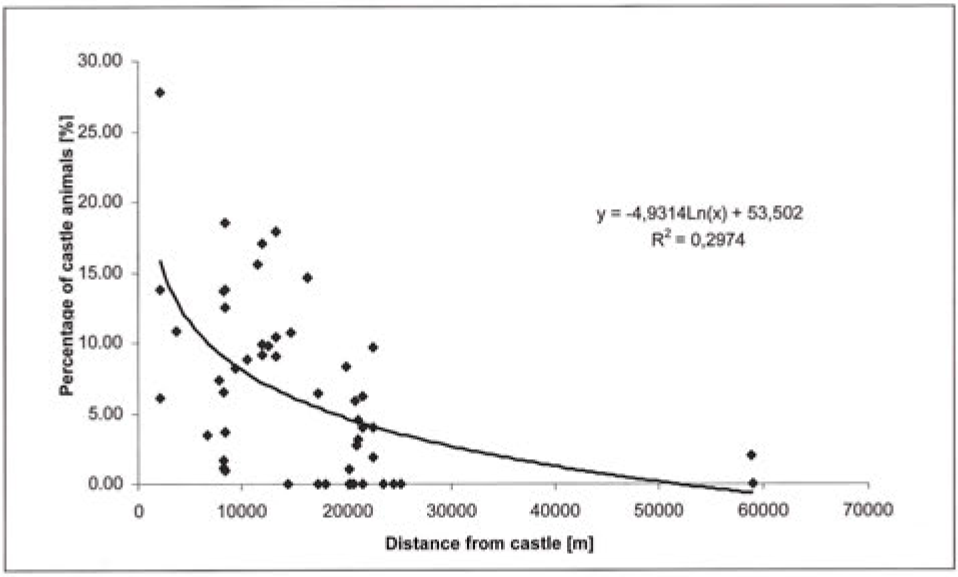

Figure 18: Regression curve showing the percentage of adult, female common pipistrelles banded at Marburg Castle and recaptured in maternity roosts, in correlation to their distance from the castle. This is based on 51 calculations from 268 recaptures in 33 villages (compare table 6).

Table 7: Number of villages/colonies and individuals of common pipistrelles in each distance classification around Marburg Castle, giving the percentage of recaptured bats from the castle.

distance classification:	designation given to each circular area radiating from the hibernaculum in Marburg Castle
villages/colonies:	number of villages in the sector
individuals:	result from villages x 88
percentage of castle animals:	average value per ring area from the regression line
castle animals:	number of common pipistrelles calculated from individuals and percentage of bats from the castle

Distance classification	Villages/colonies in distance classification	Individuals in distance classification	Percentage of castle animals [%]	Castle animals (individuals)
< 5,000 m	11	968	14	136
5,000<=x<10,000	46	4,048	10	405
10,000<=x<15,000	58	5,104	7	358
15,000<=x<20,000	71	6,248	5	312
20,000<=x<25,000	87	7,656	4	303
25,000<=x<30,000	106	9,328	3	280
30,000<=x<35,000	140	12,320	2	246
35,000<=x<40,000	148	13,024	2	261
Total	**667**	**58,696**		**2,301**

4.1.2 Regional and national distribution and abundance

Due to the splitting up of the species *Pipistrellus pipistrellus* into *P. pipistrellus* (common pipistrelle – 45 kHz type) and *P. pygmeaus* (soprano pipistrelle – 55 kHz type), nearly all previous information about the density and frequency of the common pipistrelle can no longer be used, because it is not known which species were investigated. Both species have obviously lived sympatrically for a long time, for example in Great Britain (BARLOW & JONES 1999).

Meanwhile the soprano pipistrelle has been discovered in Hesse (AGFH 2002) but overall it seems that the common pipistrelle clearly predominates. Prior to 1996 at least 20 villages in the Marburg-Biedenkopf district were known to have maternity roosts (unpublished data). There had been only occasional counts and no population estimates and so it is impossible to compare current numbers with those known before the project.

Estimations are lacking about the absolute frequency of the common pipistrelle in Hesse. The relative frequency of the "probably most frequent species of bats in Hesse" is mentioned (AGFH 1994). Even in other German regions, information about the population density is mostly lacking (for example TRESS 1994, HECKENROTH et al. 1988). MÜLLER (1993) mentions a total 1,000 animals over the area of 16 standard topographic survey maps in Baden-Wuerttemberg, which would be about 0.5 individuals per km², a factor of 50 less than in the project area. Information about the density and spread of *P. pipistrellus* in Germany is still lacking. BOYE et al. (1999) describe the common pipistrelle as "the most frequent bat species in Germany". According to our results, experience and the literature, everything points to the fact that the common pipistrelle (*P. pipistrellus* 45 kHz) really is the most frequent species of bats in Germany. In other European countries, there is only little information available for comparison (GAISLER 1979, SPEAKMAN et al. 1991, THOMPSON 1990).

Population density estimates of the two *Pipistrellus* species combined (see above) are approximately one adult common pipistrelle per 10.7 ha (±1 ha) (which is 10 common pipistrelles per km², THOMPSON 1990) and 18.2 (female) individuals per km² (SPEAKMAN et al. 1991). Only GAISLER (1979) counted considerably higher densities of bats (possibly both species of bats taken together) with more than 300 individuals per km² for an area in Romania. When these statistics are examined more closely, however, they concern only visually ascertained densities in hunting grounds (activity densities) in an area of about 40 ha, which can hardly be compared with general population densities.

4.2 Serotine bat (*Eptesicus serotinus* [Schreber, 1774])

4.2.1 Distribution and abundance within the project area

Maternity roosts of the serotine bat have been found in 8 villages in the area of investigation up to now. Five of them are new colonies found during the term of the project (compare figure 19). The number of maternity roosts which have been found up until now is about 37, of which 7 were known at the beginning of the project. This is by no means a final number, because not all roosts could be searched for and discovered. Additionally, 32 individual roosts or male roosts of this species of bats were recorded (4 of them already before the project). Flight observations and indications of individual roosts could be made in a further 14 villages. Winter finds of serotine bats were very rare – no more than one individual was ever found at any one village. Except for two traditionally used hibernacula (known since 1990), single animals are found now and again in winter during renovations to walls or roofs.

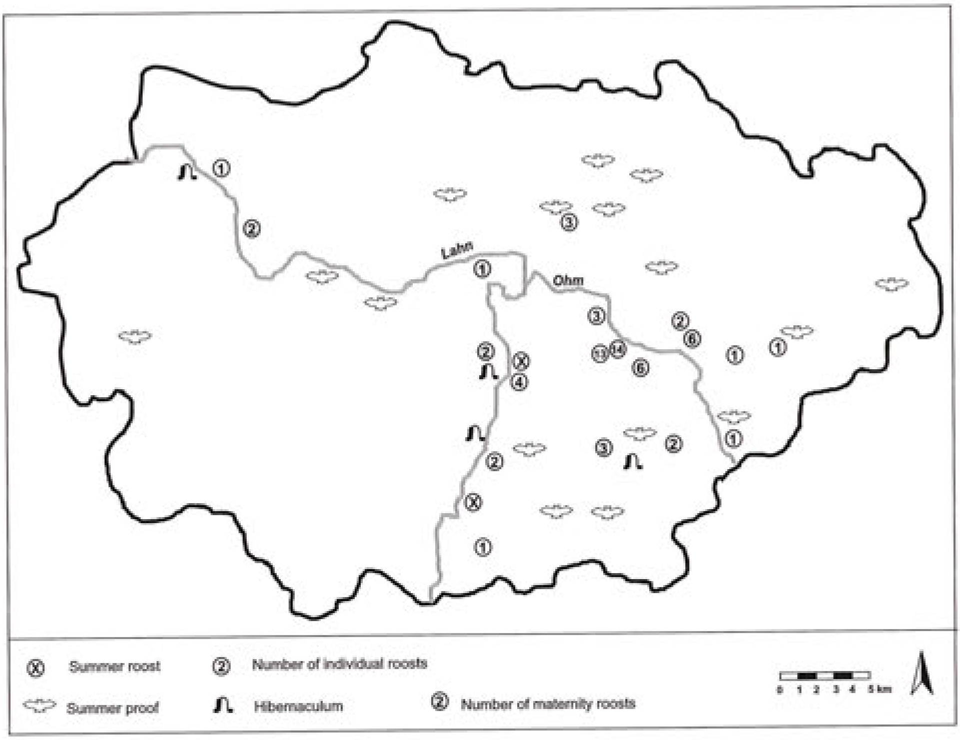

Figure 19: Localites within the project area showing occurrence of the serotine bat (*Eptesicus serotinus*).

Figure 20: Serotine bat.

gle roosts of female greater mouse-eared bats were found on buildings (n = 9). Furthermore, several mating roosts could be found in different positions on buildings (compare table 3). These are mostly crevice roosts, of which a great number are outside, but some are also on the inside of the buildings' walls. The latter are only discovered by exception, mostly with the help of telemetry studies (compare AUDET 1990). The importance of roosts in buildings is probably generally underestimated for the greater mouse-eared bat. A percentage of these roosts are mating roosts. Mating roosts are often found in attics and so they are estimated to be frequent (GÜTTINGER et al. 2001). Usually, only a dozen males or male roosts will be found in an area holding several thousand females. It is obvious that only a small fraction of the actual number of mating roosts are discovered, despite a supposedly relatively balanced ratio of the sexes (as can be ascertained in hibernacula) (for example ZAHN 1995). The real distribution of mating roosts and male roosts seems to have been investigated insufficiently, the choice of roosts by males and individual animals is not known.

The estimation of the significance of tree-hollows for the greater mouse-eared bat is just as difficult as for single roosts on buildings. Because of a lack of observations, the significance is as a rule classified to be lower (MESCHEDE & HELLER 2000). During our telemetry studies, 9 of 14 radio-tracked females stayed one or several nights in tree-hollows in the forest (compare chapter 7.3.3). It was not always possible to invest the technical effort necessary to locate the roost exactly. In many cases emergence observations were carried out or favourably placed tree-hollows were inspected with a torch and so a direct proof of roosts in hollows could be made (beeches and one oak tree). The radio-tracked bats were captured several times at their tree-hollows. In one case in early autumn 2000 a radio-tracked young bat was caught at a tree-hollow in a beech forest one kilometre away from the maternity roost. Apart from the radio-tracked animal, two other greater mouse-eared bats left the tree-hollow. In another case five female adults could be caught in front of a tree-hollow at the beginning of July (compare chapter 7.2.3). Another animal escaped, so that at least 6 greater mouse-eared bats spent the day together in this roost. The day before, another radio-tracked animal had been located in this hollow, so that a proven 7 greater mouse-eared bats used this tree-hollow on these two days.

The light barrier and video observation of the colony in Gladenbach shows that the females did not return to their roosts on bad-weather nights. Nearly the whole group of about 300 animals assumedly stayed in their hunting grounds, namely to the most part in tree-hollows (see telemetry results above). Even though these roosts are only used sporadically, they have to be available quantitatively for all animals of the colony. Therefore, tree-hollows also play an important role for greater mouse-eared bats.

The number of proven female greater mouse-eared bats in the investigation area is about 500 individuals. The arithmetic density is about 0.42 females per km^2 (that corresponds to 0.84 females and males per km^2), thus on a similar scale as the common pipistrelle and the serotine bat. The results for the greater mouse-eared bat are more "reliable", because those for the common pipistrelle and the serotine bat could be higher due to their lower recording degree (see figure 11, chapter 3.2).

4.3.2 Regional and national distribution and abundance

On the basis of the data of SCHÄFER (1998) and SYRING (2000) there is an average density in Hesse of about 0.33 adult females per km^2 (that corresponds to about 0.66 individuals per km^2). ZAHN (1995) mentions 1.4 individuals per km^2 for Bavaria. According to

MESCHEDE & HELLER (2000) there are 0.95 animals per km². In Baden-Wuerttemberg 0.58 individuals were calculated by MÜLLER (1993). Corresponding to the northern distribution border (compare STEBBINGS & GRIFFITH 1986), the greater mouse-eared bat clearly gets rarer the further north in Germany one goes (compare HIEBSCH & HEIDECKE 1987, BORKENHAGEN 1993). Of the 20 colonies in Lower Saxony, the majority are situated in the south of this state (BOYE et al. 1999, HECKENROTH et al. 1988).

The population density of 0.84 greater mouse-eared bats per km² is a little bit higher than the average in Hesse and is comparable with the figures for the south of Germany. The population density is clearly higher in eastern Europe, for example in central Bohemia, where 2 to 3.5 individuals per km² were calculated (HORÁČEK 1985).

4.4 Natterer's bat (*Myotis nattereri* [Kuhl, 1817])

4.4.1 Distribution and abundance within the project area

One of the greatest misjudgements of bat stocks was brought to light by the proven existence of the Natterer's bat in the project area. At the beginning of the investigation there was no maternity roost known in the Marburg-Biedenkopf district. According to this and other knowledge concerning the frequency and occurrence of this species in Hesse (for example KALLASCH & LEHNERT 1994b), the Natterer's bat was not considered in the original conception of the "house-dwelling bat project".

The first maternity roost (on a building) was found in the second year of the investigation (1998). The specific search in villages for the occurrence and roosts of the Natterer's bat began in from summer 1999. Because of the multiple sightings of Natterer's bats hunting in cowsheds, a new search pattern could be developed. Many villages (n = 78) were specifically investigated to find Natterer's bats or bats hunting in cowsheds. This species of bat could be recorded in nearly half of the villages (37 villages). Maternity roosts were found in 11 villages (compare figure 22), mostly thanks to intensive searching. The recorded abundance of the Natterer's bat in the investigated area was clearly higher than that of the serotine bat (about 20 detections in villages, 8 maternity roosts). In principle the roosts of the Natterer's bat are more difficult to find in villages. Because of their quieter call and mainly low flight, they are not so conspicuous as the serotine bat or the common pipistrelle. In nearly all villages where roosts were searched for intensively on the basis of flight observations, these roosts could be found (also by means of telemetry). No more searching was carried out in more than 20 villages. However, it can be expected that roosts of the Natterer's bat can be found in nearly all villages in which they were observed hunting. Projecting for the whole investigated area, Natterer's bats should occur in at least 70 villages out of 150. It can be supposed that the presence of maternity roost colonies could be recorded in 30–50 villages.

Because of the frequent roost switching of this species, it is hardly possible to give details for average sizes of the maternity colonies. A determination of the number of bats requires costly investigations (banding, in particular). In the administrative district, the size of the colonies varies between 11 and 49 adult females. On average, 23 individuals can be found in one colony (compare figure 29). Therefore the total number of the counted female Natterer's bats is only about 186 (counts on 8 maternity roosts) until now. Given 30–50 (hypothetical) maternity roosts, 690–1,150 females would be present. The actual measured density of 0.16 female Natterer's bats per km² would rise to one female per km², which is more likely to tally with the real numbers in the investigation area.

In winter Natterer's bats are found mostly individually in galleries or caves. Only few individuals can be recorded in the area.

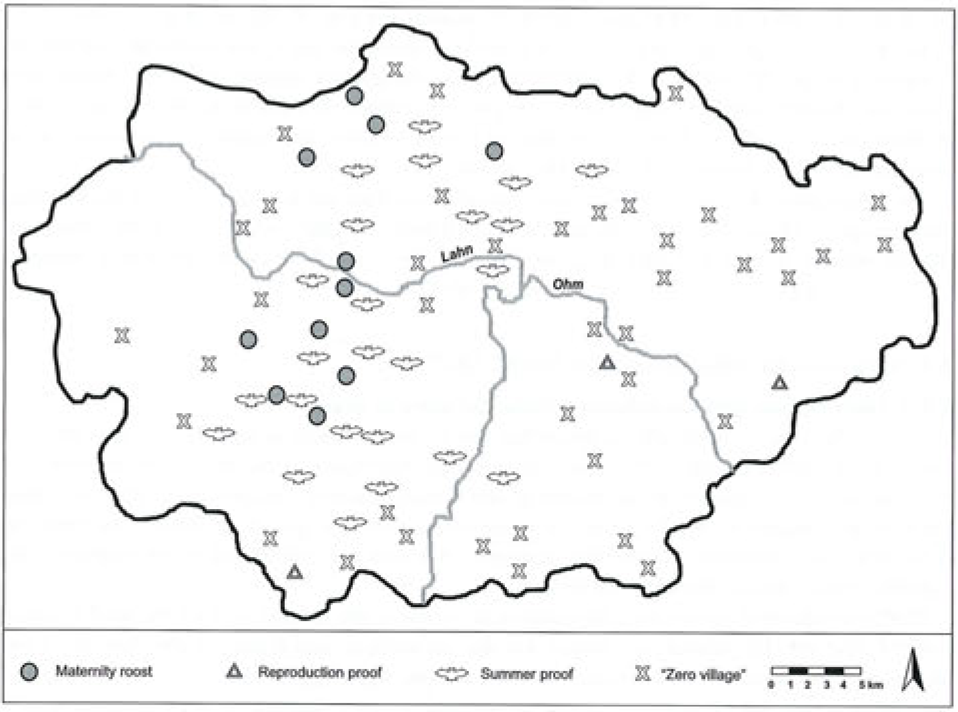

Figure 22: Villages where the Natterer's bat (*Myotis nattereri*) exists in the project area. In contrast to the other distribution maps, "zero villages" are the villages where Natterer's bats were especially searched for but not found. The summer records are as a rule records of the Natterer's bat in cowsheds. The hibenacula are not marked on this map. However they are the same hibernacula as for the greater mouse-eared bat (compare figure 21).

Figure 23: Natterer's bat in a cowshed.

The phenomena of bats favouring certain sections of the total project area is especially clear in the case of the Natterer's bat. Numerous occurrences were found in the western part of the project area, with no evidence of this species in the eastern part. A regional, ecological analysis could demonstrate that the presence of heavily forested areas and streams influence the distribution of this species (compare chapter 11.2.2).

4.4.2 Regional and national distribution and abundance

For a long time information about the spread and the frequency of the Natterer's bat have been reconstructed by means of winter finds (compare TOPÁL 2001). The winter visual controls could not reflect the true numbers at any time, because Natterer's bats hide excellently in their hibernaculum and a large percentage are withdrawn from human observation. The records of maternity roosts clearly turned out to be even more difficult: Up until 1993 only three maternity roosts were known in the approximately 21,000 km^2 vast area of Hesse, one in a building, the others in nest-boxes. The Natterer's bat was in general estimated to be rare and "on no account frequent" (compare KALLASCH & LEHNERT 1994b, KOCK & KUGELSCHAFTER 1996). In the whole of the GDR only five summer roosts were known until 1987 (one of them a certain maternity roost) (HIEBSCH & HEIDECKE 1987) and in Bavaria until 1977 only two maternity roosts (ISSEL et al. 1977). Meanwhile in Saxony, 22 maternity roosts are known (since 1985) (POCHA 1999). In Lower-Saxony 10 summer roosts (four of them maternity roosts) were reported up until 1988 (HECKENROTH et al. 1988), in Baden-Wuerttemberg 6 (MÜLLER 1993) and in Thuringia 12 maternity roosts (WEIDNER 1994).

The Natterer's bat was or is repeatedly described as "forest bat" or as a species mainly to be found in tree-hollows (for example BOYE et al. 1999, FRANK & DIETZ 1999). GEBHARD (1997), ISSEL et al. (1977), NATUSCHKE (1960) and SCHOBER & GRIMMBERGER (1998) could not prove the presence of any Natterer's bat in villages. The current increasing observation of this species in areas of human settlement leads to differentiated designations ("house-dwelling bat", ILLI 1999) or to no exact classification (compare MESCHEDE & HELLER 2000).

According to our present results, we must mention the Natterer's bat as second most frequent species of bat in villages and housing estates. More frequent is only the common pipistrelle, whose presence is considerably easier to prove.

By means of intensive investigations, hibernacula of Natterer's bats with some thousand winter sleepers could be found in Bad Segeberg and in Berlin and have gained recognition as mass hibernacula (SCHOBER & GRIMMBERGER 1998). These hibernacula give first indications of the actual frequency of the Natterer's bat in the surrounding area.

According to our biased search for bats – only in areas of human settlement and not in the forest – the Natterer's bat has to be classified as a typical and frequent "house bat". During other investigations in the Marburg-Biedenkopf district, which were carried out in forests (SIMON, unpublished), Natterer's bats were found nearly every time where bats were captured with a net or surveyed with a detector. We can proceed from the assumption that this species of bats can be present in high numbers in the forest and in areas of human settlement. TRAPPMANN & CLEMEN (2000/2001) call the Natterer's bat "forest bat". They found roosts of this species not only in tree-hollows but also in bat boxes, attics and in cowsheds in their telemetry investigations.

4.5 Whiskered bat (*Myotis mystacinus* [Kuhl, 1817])

4.5.1 Distribution and abundance within the project area

At the beginning of the investigation there were only few clues concerning distribution and abundance of the whiskered bat. The occurrence of this species could be roughly derived only from regular winter controls. Four summer roosts had been known until 1999, amongst them three maternity roosts (compare KALLASCH & LEHNERT 1994c und see table 3). During the project, a further 24 roosts were mapped in buildings in 13 villages, as well as two roosts in a village where a maternity roost was already known. Ten new maternity colonies were found. The records of this species are distributed over the whole investigation area (see figure 24). The colony sizes lie between 69 and 112 individuals – the true number could only be determined as an exception. Whiskered bats are found in most of the galleries and caves of the project area, which are usually appropriate for use as hibernacula. In most cases, only single animals are found. Larger numbers (> 50 animals) are known in galleries of neighbouring administrative districts.

Roosts of the whiskered bat in areas of human settlement are clearly more difficult to map than roosts of the common pipistrelle or serotine bat. Colonies which left or switched their roosts during maternity period were not found again despite an intensive search (it cannot be discounted that some colonies found roosts in tree-hollows in the forest). It can be supposed that only a small percentage of the roosts have been detected up to now, similar to the case of the Natterer‘s bat. The maximum sum of all counted adult females of 10 colonies is 582, which means that on average 58 adult females are found per colony. Based on these figures,

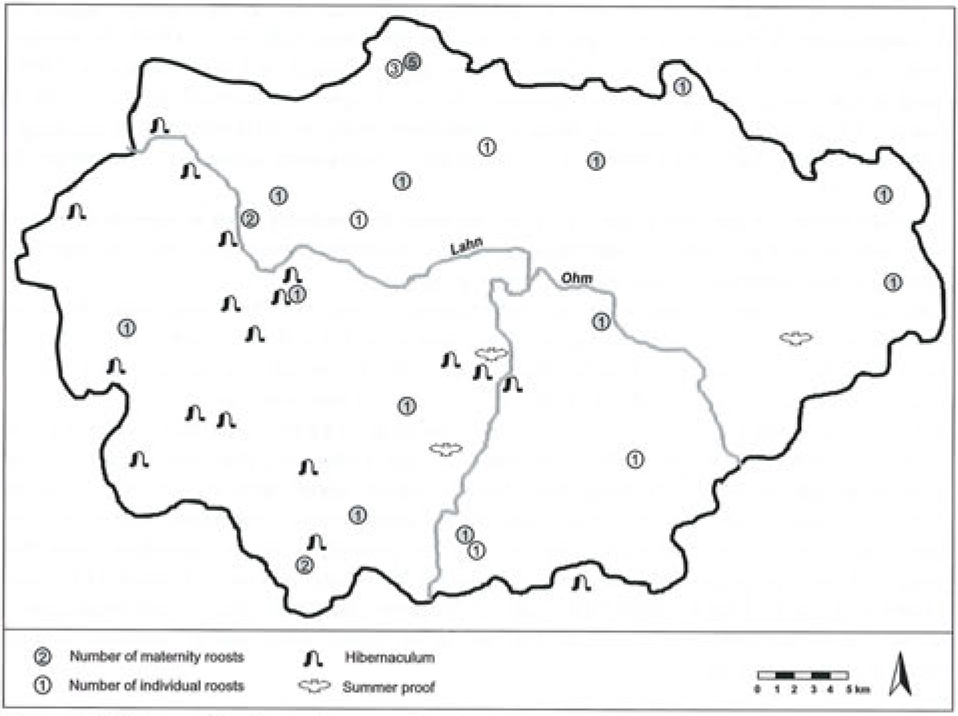

Figure 24: Villages within the project area where the whiskered bat (*Myotis mystacinus*) was found.

a minimum average density of the whiskered bat can be calculated for the investigation area, namely about 0.49 females per km^2.

4.5.2 Regional and national distribution and abundance

Until the middle of the 1980's, only few maternity roosts of the whiskered bat were known (about 10). In the following years the number of records in Central Europe increased continuously (TUPINIER & AELLEN 2001). In Hesse, 7 maternity roosts (or proof of reproduction) were known until the year 1994 (KALLASCH & LEHNERT 1994c). In Thuringia there were 22 maternity roosts (WELSCH 1994), in Saxony 15 (ZÖPHEL & WILHELM 1999), in Lower Saxony two (HECKENROTH et al. 1988), in Schleswig-Holstein none (BORKENHAGEN 1993) and in Baden-Wuerttemberg 8 (MÜLLER 1993). In almost all regions of Germany the winter records predominate over to the summer ones (compare KIEFER et al. 1996, KALLASCH & LEHNERT 1994c). This highlights a deficit in summer investigations which require a greater effort to be carried out.

In Europe, the whiskered bat was predominantly classified as rare (e. g. STEBBINGS & GRIFFITH 1986), for Central Europe a decrease in numbers was supposed (RICHARZ & LIMBRUNNER 1999). Meanwhile, regional increases in numbers are proven in Germany, based on controls of hibernacula (compare KIEFER et al. 1996).

4.6 Common long-eared bat (*Plecotus auritus* [Linnaeus, 1758])

4.6.1 Distribution and abundance within the project area

The presence of common long-eared bats of the genus *Plecotus* can be proven in almost all big and accessible church attics in the project area by means of their guano. Also in other spacious attics with infrequent use and good access for bats, traces of long-eared bats were found in many villages. A determination of species, however, is not possible to carry out from the excrement. In the project area – as in most German regions- the trend was a predominance of grey long-eared bats over common long-eared bats in building roosts (see below).

Common long-eared bats are distributed over the whole project area (see figure 25). Their precense was proven in most of the known hibernacula (galleries, cellars, bunkers etc.), while grey long-eared bats are only found in very few hibernacula. Common long-eared bats are also regularly found in nesting boxes in the forest, whereas grey long-eared bats are not.

Despite the wide distribution of common long-eared bats, their maternity roosts on buildings are rarely found. Here, methodological reasons, which are partly responsible for this fact, must be considered: most maternity colonies only have low numbers of individuals and are therefore inconspicuous in small building roosts, e. g. behind wall cladding or in crevices in half-timbering. Hence, they are difficult to map systematically.

At the beginning of the project two maternity roosts of the common long-eared bat within the project area were already known, but not in buildings. During our investigations, we detected five new colony villages with 8 roosts in buildings (compare table 3). For two of the colonies the number of adult females could be determined: five and 16 individuals.

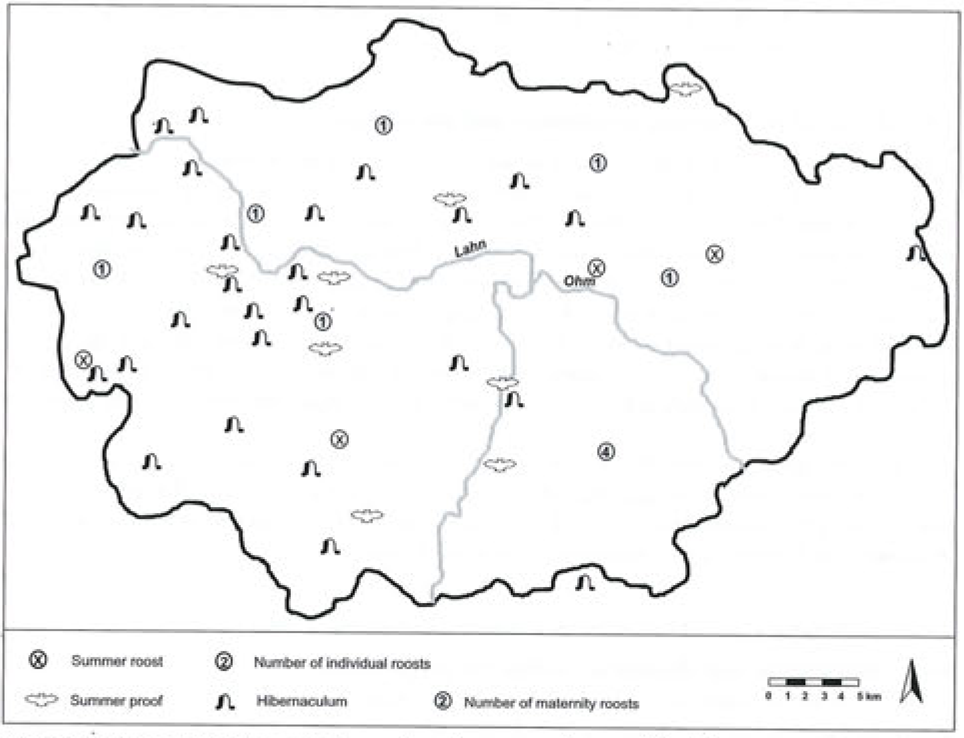

Figure 25: Villages within the project area where the common long-eared bat (*Plecotus auritus*) was found.

4.6.2 Regional and national distribution and abundance

The common long-eared bat which is widely spread in Central Europe is often found in heavily forested areas (SCHOBER & GRIMMBERGER 1998, ENTWISTLE et al. 1997). While the roosts of this species that are in buildings are most often in attics in Great Britain (ENTWISTLE et al. 1997), this classification is more difficult to establish for Germany, where the common long-eared bat is frequently classified as forest bat (e. g. FUHRMANN & GODMANN 1994, KULZER 1989). In Thuringia, however, most of the maternity roosts were detected in buildings (FISCHER 1994a).

It is especially difficult to obtain population numbers for adaptable bat species like the common long-eared bat, which occur in areas of human settlement as well as in the forest. As our investigations regarding roosts were limited to areas of human settlement, statements about densities for a species whose population lives to a considerable extent in the forest must be excluded. For a general estimation of possible densities, 1.6 common long-eared bats per km^2 in Great Britain can be mentioned (SPEAKMAN et al. 1991).

4.7 Grey long-eared bat (*Plecotus austriacus* [J. B. Fischer, 1829])

4.7.1 Distribution and abundance within the project area

Concerning the possibility of locating roosts in buildings, the same conditions apply to the grey long-eared bat as for the common long-eared bat (see chapter 4.6.1). At the beginning of the project, four proven maternity roosts were known in the project area.

The exact location of the roosts in the buildings was only determined for two of the colonies. Within the framework of our investigations, 6 further maternity roosts (villages) with 7 roosts in or on buildings were found (compare table 3).

While the common long-eared bat is for the most part distributed evenly over the project area, the grey long-eared bat is evidently lacking in the west (see figure 26). This corresponds with the knowledge concerning the spread of this species. It favours lower, that is, warmer locations (see below). Especially conspicuous is rare occurrence of the grey long-eared bat in the "usual" hibernacula. In contrast to the common long-eared bat, grey long-eared bats are rarely seen in winter, and then mostly as single individuals. Furthermore the winter finds of the grey long-eared bats are almost exclusively in close proximity to their summer occurrences. Here, their subterranean roosts (e. g. galleries or cellars) are usually remarkably dry. The requirements of the grey long-eared bat, the common pipistrelle and the serotine bat seem to be quite similar in this regard: of about 70 known, regular hibernating sites in the project area, there are two roosts which are exclusively used by grey long-eared bats (quite dry cellars) and two further hibernacula, which are the only ones used regularly by common pipistrelles. Single serotine bats that had not been seen in any other hibernacula, were also recorded regularly in these two roosts. Over recent years, several findings of single hibernating grey long-eared bats (four) near the facades or intermediate roofs of residential buildings were reported. Apparently, roosts in buildings are also important for this species during winter.

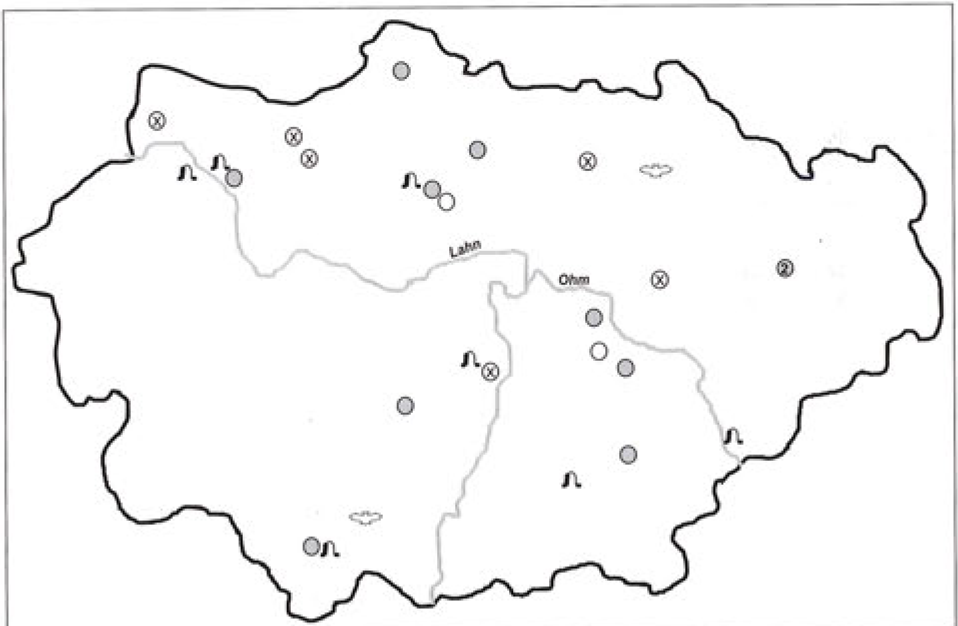

Figure 26: Villages within the project area where the grey long-eared bat (*Plecotus austriacus*) was found.

4.7.2 Regional and national distribution and abundance

While the common long-eared bat occurs in northern Europe, the grey long-eared bat, which favours warmth, reaches its distribution limit along the 53rd latitude (compare MITCHELL-JONES et al. 1999, SCHOBER & GRIMMBERGER 1998, STEBBINGS & GRIFFITH 1986).

The records of occurrence of grey long-eared bats in Hesse can be described as rather scanty. Until the year 1994 only about 9 maternity roosts were known (FUHRMANN 1994). Winter findings were even rarer. A similar picture is shown by MÜLLER (1993) for Baden-Wuerttemberg, while there do exist considerably more proofs of their occurrence in Thuringia, especially in the south of the state (FISCHER 1994b). The data on the occurrence of this bat species in Saxony evidently indicates that areas of higher altitute (e. g. low mountain ranges) are avoided (SCHOBER 1999). It is not possible to give statistics on the nationwide frequency and population growth trends, due to insufficient data on the population size (compare BOYE et al. 1999).

Due to the synanthropic way of life of the grey long-eared bat and the insufficient knowledge about its numbers, it can be safely assume that this species was and is seriously threatened by restauration work and renovations of buildings.

4.8 Barbastelle bat (*Barbastella barbastellus* [Schreber, 1774])

4.8.1 Distribution and abundance within the project area

In the year 1998, the first maternity colony in Hesse was detected in the project area during a survey exercise. With approximately 40 adult females, this colony is among the biggest in Central Europe. Their roost is located in a big half-timbered house with quite old slate-cladded walls in need of renovation, behind which the animals conceal themselves. A further roost was discovered behind the wall-cladding of a neighbouring building. In the known hibernacula in proximity to the summer roosts, up to 20 individuals can be counted during the winter months. So far the summer and winter findings of this species limit themselves to 150–200 km^2 in the northwest of the project area.

4.8.2 Regional and national distribution and abundance

The barbastelle bat can be found over large parts of Central Europe and reaches its northern limit in southern Norway, however has not been found in large parts of northern Germany. After dramatic stock decreases between the 1950's and 1970's in large parts of Germany (and of Central Europe) the barbastelle bat has become very rare over the last decades and has completely disappeared in some regions (z. B. FELTEN & KOCK 1979, ISSEL et al., KULZER et al. 1987).

From beginning to end of the 1950's, there were still known mass occurrences (hibernacula) with hundreds of animals in some regions of Germany (e. g. FRANK 1960; HOEHL 1960). However, these have completely or to the most part disappeared (compare FRANK 1971; PIEPER 1971). Only in Bavaria (5–10 colonies), Thuringia (14 colonies) and Brandenburg have apparently quite big populations been preserved (compare BOYE et al. 1999). In Hesse, until the 1990's this species was supposed to have almost died out (compare KOCK & ALTMANN 1994). Comparative GIS-investigations at maternity roosts in Bavaria, Thuringia and Hesse (one colony) led to the conclusion that apparently traffic and density of human settlement influence the spread of this species (see chapter 11.2.4).

4.9 Conservation status of investigated bat species according to Red Lists

The Red Lists of the federal government and the federal states cannot be easily compared with each other. The valid versions were published at different times and some of these publications are many years old. As the knowledge about occurrence and ecology of bats has been increasing rapidly in recent years, the evaluation basis of older Red Lists concerning endangered mammals is much narrower than that of more current new versions. Furthermore, the categories of the Red Lists, their definitions and criteria have been changed time and again, so that for individual cases the original publications of the Red Lists must be consulted.

BOYE et al. (1999) have summarized the threat categories of bat species according to the Red Lists in Germany. Some of the federal states have worked out new versions, which are compiled in the German National Report 2000–2003 for the EUROBATS-Agreement (http://www.eurobats.org).

Amongst the house-dwelling species, the **common pipistrelle** is the only one not currently endangered nationwide (see table 8, BOYE et al. 1999). This classification was based on its national distribution, its numerous, not rare occurrence, also in areas of human settlement, as well as on indications to a stable or even in some regions increasing stock. This estimation still applies for this species. No other bat species has revealed so many mass hibernacula in almost all parts of Germany up to now, namely Demmin ("Bartholomaei church"), Hamburg ("Parking garage"), Heidelberg ("castle"), Hildburghausen ("Veste Heldburg"), Korbach ("factory"), Marburg ("castle"), Mayen ("basalt gallery"), Freiburg ("cathedral") und Osterode ("lime gallery"). In all these roosts common pipistrelles were captured and examined within the project's framework, so that it could be guaranteed that they were indeed common pipistrelles, and not possibly soprano pipistrelles. Apart from this, the common pipistrelle is a strikingly adaptable species, which settles in different build-

Table 8: The investigated bat species and their Red-List-status in Germany (modified according to BOYE et al. 1999, http://www.eurobats.org) D = Germany, BW = Baden-Wuerttemberg, BY = Bavaria, BE = Berlin, BB = Brandenburg, HH = Hamburg, HE = Hesse, MV = Mecklenburg-Western Pomerania, NI/HB = Lower Saxony and Bremen, NW = North Rhine-Westphalia, SL = Saarland, RP = Rhineland-Palatinate, SN = Saxony, ST = Saxony-Anhalt, SH = Schleswig-Holstein, TH = Thuringia, 0 = extinct, 1 = in danger of extinction, 2 = seriously endangered, 3 = endangered, R = extremely rare species and species with geographical restriction, G = threat can be supposed, but status unknown, 4R = stock risk due to decrease, V = near threatened, I,II und RG = endangered migrating species, visitors, n = currently not endangered, ? = occurence in this state is not assured, – = no regular occurrence proved.

	Federal state															
Bat species	SH	HH	NI/HB	NW	HE	RP	SL	BW	BY	BE	BB	MV	TH	ST	SN	D
P. pipistrellus	3	2	3	n	3	3	V	3	4R	3	V	4	3	2	V	n
E. serotinus	V	3	2	3	2	1	3	2	2	3	3	3	2	2	3	V
M. myotis	1	1	2	2	2	2	1	2	3	1	1	2	3	1	2	3
M. nattereri	3	?	2	3	2	1	1	2	2	2	2	3	3	2	2	3
M. mystacinus	G	-	2	3	2	2	1	3	3	1	1	1	3	1	2	3
P. auritus	3	2	2	3	2	2	1	3	4R	2	3	4	n	2	V	V
P. austriacus	-	-	2	R	2	2	1	1	2	1	2	-	2	2	2	2
B. barbastellus	-	-	1	1	1	1	-	1	1	0	1	1	2	1	1	1

ing roosts and can be called euryoecious, also with regard to its hunting habitats. The classification into the category "2 – endangered" on the Red List in Hesse corresponds to the state of knowledge at the beginning 1990's and would have to be changed into "not endangered" for a new edition.

The **serotine bat** has a national standing of Red List category "V" (near threatened), however, in 7 federal states it is classed "endangered" or "critically endangered". For the national classification it was decisive that the species is not rare in the northwest of Germany and occurs commonly in the village-strewn rural areas and also towns of that region. In the rest of Germany it is less frequent, but still occurs nationwide. The stocks were estimated as being mostly stable, though there were indications of serious decreases of stock due to inconsiderate building renovations. This was also the reason for listing the species is as near threatened. In Hesse itself, the serotine bat has been classified "endangered" on the Red List up to now. The more intensive search within the project's framework revealed clearly higher densities for this species than is known in other villages in Hesse. Similar densities must be supposed for further areas of the state. Due to this, the current classification of the serotine bat in the Red List of Hesse must be revised.

The **greater mouse-eared bat** is "vulnerable" nationwide. This is a lower category of threat than is the case in the majority of federal states (in six federal states the species is even "critically endangered"). The estimation of the federal government was based on the bat's wide distribution in Germany and the fact that the greater mouse-eared bat is not rare in several of the federal states, in contrast to other bat species. Nevertheless, the mouse-eared bat stocks decreased strongly in the 1950's to 1970's, showing, however, a recovery in the meantime – also in the project area (comp. AGFH 2002). The formation of big to very big maternity colonies, mostly situated visibly in attics, presents a special risk factor for this species. At the same time this behaviour also allows a quite good observation of the stock development with a relatively low expenditure, while other house-dwelling species often cannot be recorded due to methodological reasons (see above), and false estimations concerning threat classification can possibly result from this. A close-knit and good network of assistants, who regularly control mouse-eared bats' maternity roosts and give advice or help in the case of problems, has considerably contributed to the positive stock development of this bat species. Therefore, the classification in the Red List of Hesse should now be modified from "endangered" to "vulnerable".

Presumably the classification of the **Natterer's bat** requires revision as well – not only in Hesse, but also in some other federal states, as the recording of this species probably has considerable gaps in many villages. Possibly just a targeted survey in cowsheds, using spot checks (see chapter 3.1.1), could notably improve the current data on the distribution and abundance of this species. The classification into the category "vulnerable" by the federal government, was based on the estimation of a wide distribution without special ties to specific types of habitats. After decreases in the 1950's to 1970's the stocks have stabilized again or even increased slightly. A risk factor for the species is apparently given due to the preference of certain hibernacula, in which the animals from a big catchment area concentrate (e. g. Spandau Fortress and Segeberg cave).

The Red Lists are still an important instrument towards conservation: they describe the state of biodiversity, provide a standard for the evaluation of landscape elements and habitats, aid public awareness work for conservation and inform experts and politicians on the necessary measures to reach a sustainable use of nature. A well-founded, up-to-date data base is necessary for a Red List. The results of the systematic compilations within the project's framework allow the conclusion that the spread, stock sizes and stock developments of house-dwelling bats in large parts of Germany are insufficiently known or even falsely estimated. For those bat species roosting in forests the gap in knowledge is even greater. Therefore, large programs to record the actually occurring bat populations, their habitats and migration need to be developed and realized (compare e. g. LIMPENS & ROSCHEN 1996, DIETZ & SIMON 2002). Towards this aim, it is important to strive for a standardized procedure for gathering data (choice of methods, intensity of compilation etc.) and evaluating bat stocks at national level or in all states. In this way, the Red Lists can continue to fulfil their function. In addition, the Red Lists should be further developed and optimized, which includes a standardization of categories and criteria (comp. SCHNITTLER et al. 1994, BINOT-HAFKE et al. 2000).

4.10 Summary

Established frequency of bats in areas of human settlement

- The numerous surveys and investigations were carried out with a huge recording effort of more than 13,000 working hours. An extended public awareness campaign leads to numerous roost reports which, however, relatively soon become less and less. Most roosts and bat occurrences are found through a targeted search. The success of detector surveys does not only depend on the number of participating assesors, but also on the frequency of inspections: repeated surveys help to find further roosts.
- In the villages of the project area, 534 bat summer roosts of 12 bat species were detected at buildings, within the framework of the investigations. With the exception of the Daubenton's bat all occurring species used buildings above-ground.
- At least 28,584 bats were captured during the investigations between 1997 and 2001. Here, 20,382 individuals were banded with arm-clips.
- The determination of occurrence and abundance of bats in a certain area is considerably characterized by the methodological procedure. Hence, the most frequently found summer roosts are those of the species which behave as follows:
  - call loudest (serotine bat, common pipistrelle); or
  - form big and very big colonies (greater mouse-eared bat); or
  - leave their roost early in the evening and are thereby conspicuous (serotine bat, common pipistrelle); or
  - swarm *strikingly* at the roost (common pipistrelle); or
  - are found in attics (greater mouse-eared bat, long-eared bats); or
  - present a striking behaviour, as for example to hunt in cowsheds (Natterer's bat); or
  - are mainly present in areas of human settlement (grey long-eared bat, serotine bat, common pipistrelle, greater mouse-eared bat, whiskered bat).

Nearly all statements about distribution and abundance are therefore dependent on methods (see figure 27) and it turns out to be difficult to compare species or regions. It has been known for a long time that maps showing the distribution of animal species are at the same time maps showing the presence of surveying people. The methodological deficits in the maps are neither comprehensible nor correctable. As the Red Lists and diverse methods of protection are based on these figures and data bases, their comprehensive improvement and standardisation is to be called for. For bats, this has already been explained in detail by LIMPENS & ROSCHEN (1996). With a further standardisation of the employed methods and a more intensive application, some of the distribution maps and the Red Lists would have to be modified.

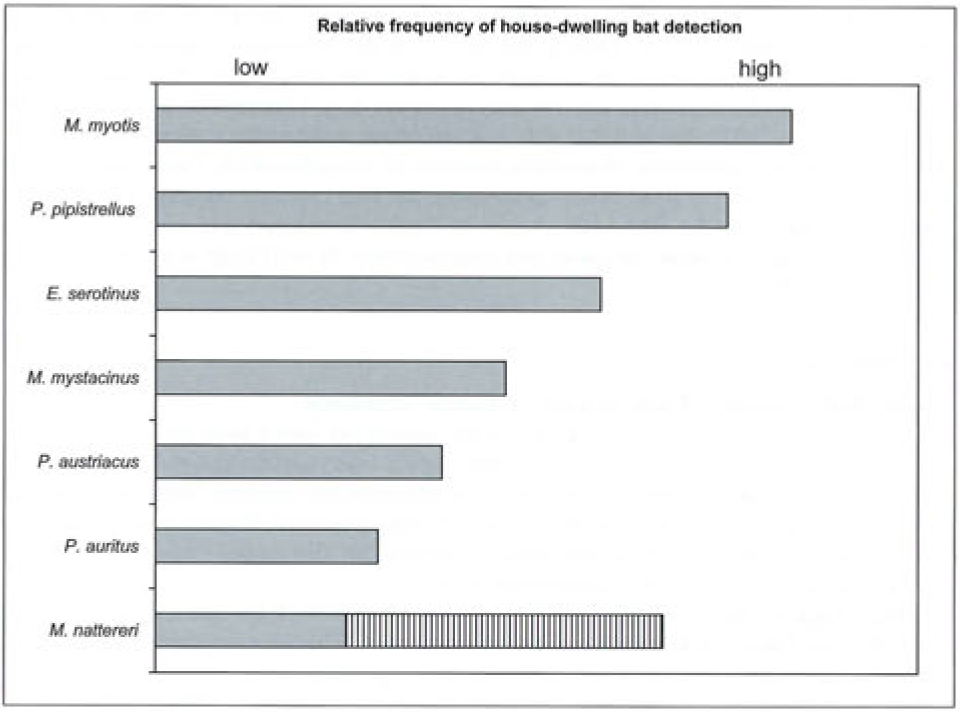

Figure 27: Methods best applied to establish frequency of house-dwelling bats. The greater mouse-eared bat can be recorded systematically very well, because of its conspicuous maternity roosts. Common pipistrelles, in contrast, behave more strikingly and have quite loud echo location at their disposal. For this reason, they are quite easy to map. The hatching indicates that the appropriate survey method is more efficient in Natterer's bat in many villages (where there are cowsheds which can be checked).

Bat stocks – regional and national occurrence

- The common pipistrelle is clearly the most frequent bat species in the project area and in all Hesse. Average densities of 25 common pipistrelles per 10 ha can be expected in most of the regions in Hesse. The number of more than 440 roosts in the project area indicates how many bat roosts can principally be expected in villages. In principle, in the central part of Hesse common pipistrelles can be detected in every village. Maternity roosts exist in approximately 90 % of the villages.
- It is probable that there is an average of 50 more or less current summer roosts in every village which has a common pipistrelle colony (maternity and individual roosts). This number increases accordingly in bigger villages. This means that a hypothetical administrative district with for example 100 small and medium-sized villages has about 5,000 summer roosts of the common pipistrelle! For the other species a similar number must be expected, so that altogether 10,000 bat summer roosts can be supposed to exist – only at buildings – in one single administrative district (with an area of about 1,000 km²).
- The occurrence of most of the house-dwelling bats within the project area was considerably more frequent than could be expected for this region of Hesse, according to the formerly existing data. This applies especially to the Natterer's bat which has been classified

as rare until now, and now must be regarded as one of the most frequent species in the villages of northern and central Hesse. Probably the Natterer's bat is the second most frequent species in Hesse. The calculated density values for the Natterer's bat clearly lie below the actual numbers, as only a fraction of the roosts could be recorded (furthermore, numerous roosts can be supposed to be located in tree-hollows).

- In principle, a similarly big population of the whiskered bat can be expected in central Hesse. The summer roosts of the whiskered bat could be found more easily in the villages than those of the Natterer's bat (compare figure 27). Through a targeted search in cowsheds and neighbouring buildings, the presence of roosts of the Natterer's bat is now easier to establish. The whiskered and Brandt's bat partly form quite big maternity colonies, which are on average considerably bigger than the ones of the Natterer's bat. Thus, greater densities are calculated for them, despite them being found less frequently in the villages (compare figure 28).
- The greater mouse-eared bat and serotine bat occur in relatively high densities, if one compares the values from the project area with the average values from the main areas of occurrence in Germany.
- The number of adult females per maternity colony in the project area lies between 10 (long-eared bats) and 170 (greater mouse-eared bats) (see figure 29) for each bat species.
- It must be considered that individual roosts also (often crevice roosts) play an important role for greater mouse-eared bat. Due to the methodological difficulties inherent in the recording of individual roosts, tree-hollows as summer roosts are apparently underestimated to a considerable extent. The forest habitat is generally regarded just as a foraging site for the greater mouse-eared bat. However, after the dissolvement of the maternity roosts the mouse-eared bats retire quantitatively to so-called "intermediate roosts". During the nights, nonetheless, the animals are still found in the forest. Foraging areas are preferredly situated in beech forests or similarly structured mixed woodland (with older forest stands). At the same time these forests offer tree-hollows as roosts.
- It is especially difficult to estimate the frequency of the long-eared bats. These quite softly calling and late emerging bats are the ones most frequently "overlooked" during detector surveys. Added to this, long-eared bats often form small maternity roosts which are there-

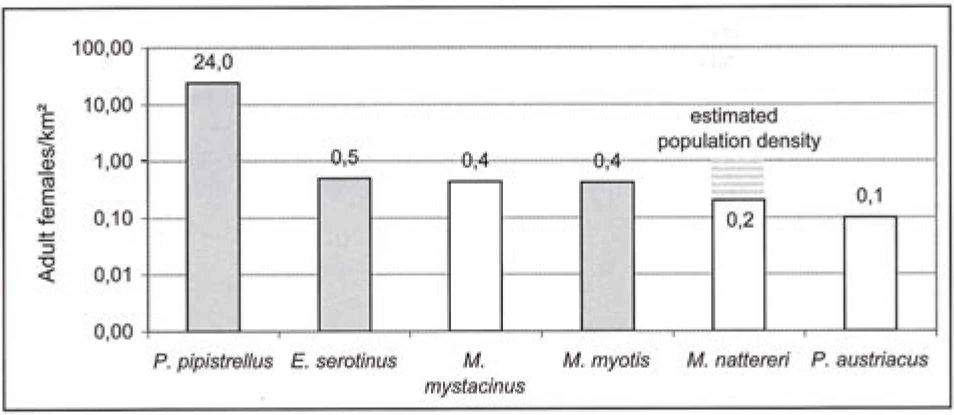

Figure 28: Average minimum population densities of adult female bats per km² within the project area. Those species which the data shows to be comparatively highly represented, are marked with a grey area. The densities for the rest of the species are clearly too low, as there are not sufficiently complete recordings. The stated density of the Natterer's bat is an estimate only (see chapter 4.4).

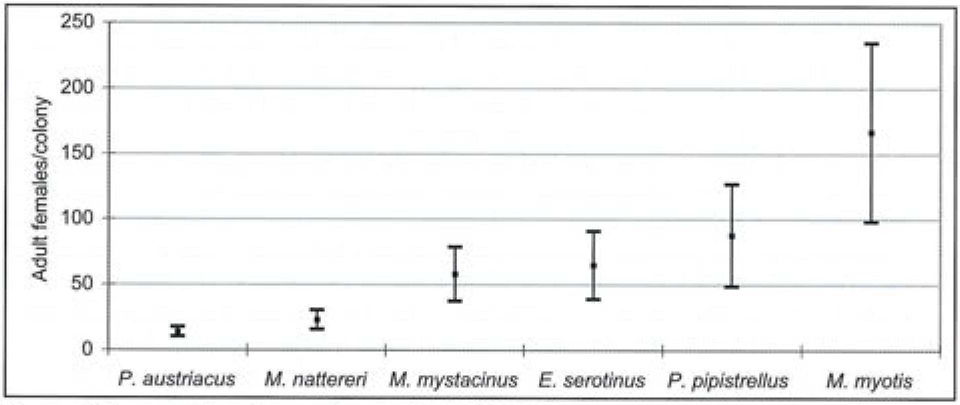

Figure 29: Average sizes of maternity colonies within the project area (including the 95 % confidence interval).

fore more difficult to find. Nevertheless, occurrences of the grey long-eared bat are proven more frequently in the villages of the project area, due to its preference for roosting in buildings. Often, one has the impression that the common long-eared bat occurs in Hesse in greater numbers than the grey long-eared bat (compare FUHRMANN & GODMANN 1994). This impression is strengthened by the fact that the common long-eared bat – in contrast to the grey long-eared bat – regularly or often appears in nest-boxes or bat-boxes, and is thus easier to record. Also in the hibernacula, the common long-eared bats can be found frequently and almost everywhere. Grey long-eared bats, in contrast, seem to have other demands concerning hibernacula (cold and dry) and are not found in the typical galleries and caves, used by numerous bats.

- Notable are the winter records and reports of grey long-eared bats (4), common pipistrelles (10) and serotine bats (4) in the area of house facades or intermediate roofs, which prove that these species pick up hibernation places at buildings above the ground. A quantification of these roosts is not possible at the moment. The meaning of these hibernacula located on or in buildings has apparently been underestimated up to now.
- With regard to the occurrance of the house-dwelling species found in the area, it can be indicated that just as with the grey long-eared bat, the Natterer's bat and serotine bat also are more or less clearly dependent on landscape or climatic factors. Concerning their respective habitat requirements, the latter two species seem to be mutually exclusive within the project area (see chapter 11.2.2 and chapter 11.2.3). Only in one village do both species occur together.

5 Requirements of summer roosts for bats

5.1 Introduction

In order to create new roosts for bats, it is important to know what roost characteristics are essential for house-dwelling bats. For this reason, certain structural parameters like type of roost, its exposition, and the state of the building were recorded (see table 9). These parameters were evaluated species-specifically, and compared with data from the literature.

Furthermore, in those bat roosts where it was possible to fix a temperature sensor, the temperature was recorded with the help of datalogger. The aim was to include a wide range of typical roosts, and also roosts of each bat species in the investigation.

Table 9: Overview of the recorded structural parameters of bat roosts.

Structural parameters	Description	Cross reference
Type of roost	Detailed description of the roost (e.g. slate siding, intermediate roof, shutters etc.)	s. table 11 s. figure 31
Category of roost	Possibly several types of roost together (e.g. cladding, crevices + hollow spaces in the cladding)	s. table 11 s. figure 30
Exposition of roost	Using a compass	s. figure 49 upto figure 53
Height of roost openings above ground level	In metres	s. figure 54 + figure 55
Location of roosts in town	Location in relation to the old village centre	s. figure 56 + figure 57
Age of buildings	Using age-categories	s. figure 60
Upkeep condition of the builidings	Buildings with or without damaged structures	s. figure 61
Hight of buildings	Using the number of levels	s. figure 62
Material of landing area	e.g. roughcast plastering, wood in half-timbering or slate	s. figure 63

5.2 Roost types and categories

Different bat species sometimes use very different types of roosts. The choice, apart from the general offer, depends on the structural quality and function of the roosts. Bats generally show a high adaptability, though this can vary depending on the species (BRIGHAM 1991). An overview of the categories of roosts used by the different bat species in summer and in winter (which covers various roost types, compare table 11), is provided in table 10. Amongst the house-dwelling bat species, there are on the one hand those hanging freely in attics (greater mouse-eared bats, horseshoe bats), and on the other hand the species that only inhabit crevices (common pipistrelle, Brandt's bat, whiskered bat, serotine bat) (for remaining species see table 10). The freely hanging species, nonetheless, are also found regularly in crevices or hollow spaces. Thus, a colony of greater mouse-eared bats, for example, can be found hanging freely in a church attic, as well as in a hollow space in a wall.

In attics, there are hanging possibilities on roof battens, timbering, beaming and roof tiles. Hollow spaces in attics are for example in non-grouted areas of walls, hollow concrete blocks, wall crevices and larger hollow spaces in peg holes or behind wainscoting.

Table 10: Overview of bat species occurrences within the different summer roosts (s) and hibernacula (w). (x) = only few occurrences.

			P. pipistrellus		*E. serotinus*		*M. nattereri*		*P. austriacus*		*P. auritus*		*B. barbastellus*		*M. mystacinus*		*M. myotis*	
			S	W	S	W	S	W	S	W	S	W	S	W	S	W	S	W
Bats inhabiting crevices	Gaps + hollow spaces in/on the facade		X	X	X	X	X		X		X		X		X		X	
	Cladding		X	X	X	X	X		X		X		X		X			
	Intermediate roof		X	(X)	X					X								
	Flat roof		X		X													
	Attic				X				X		X						X	
	Cellar	dry		X		(X)				X				X				
		humid						X				X		X		X		X)
Bats hanging freely	Attic								X		X						X	
	Cellar	dry				(X)				X								
		humid						X				X		(X)		(X)		X

The crevice roosts at buildings are often hollow spaces no bigger than 1.5 to 2 cm, so that the bat's belly and back are in direct contact with the wall's material. Buildings with cladded exteriors offer a hollow space between house wall and cladding (wood, slate, asbestos cement, metal, synthetic material, tarboard, corrugated iron, sheet metal), which is used by the bats. A frequently used type of roost is the intermediate roof. This is the hollow space between roof tiles and binding beams. Crevice roosts are also found in hollow concrete blocks, behind flat roof cladding, in crevices in half-timbering, in external blind cases, or behind shutters.

Openings into the crevice roosts are served by edges of the wall cladding, damaged places in facades and crevices in doors and window frames. Furthermore, rough materials (roughcast plastering, rough timber) are important as landing areas, from which the animals can crawl into the roost.

The bat species which roost in attics can enter through open windows, but can also get into the attic by crawling through gaps, at the ridge beam, for example.

5.2.1 Common pipistrelle

Eight roost categories were formed for 378 roosts of the common pipistrelle (see table 11), according to the roost's characteristics. On the highest level are 'roof' (flat roof and intermediate roof), 'facade' and a transitory group (intermediate roof + bordering structures) 'roof + façade'. The transitory group was characterized by the fact that the roost could not be assigned clearly and exclusively to either intermediate roof or façade or hollow concrete blocks. The group 'facade' is dominated by the category 'cladding', but also includes the mixed category 'gaps + hollow spaces in the facade' and the category 'external blind case', 'bargeboard' and 'shutter'.

The three bat species which roost in crevices, common pipistrelle, serotine bat and whiskered bat, partly use the same type of roost. But they clearly show species-specific differences concerning the use of certain roosts (see figure 30). The serotine bat was principally found in the intermediate roof of buildings, and otherwise used the attic area first and foremost. The roosts of the whiskered bat almost exclusively lay behind wall cladding and other

Table 11: Categories of roost types of common pipistrelle roosts.

	group of roost	category of roost	Result	type of roost	Result
Roof	**flat roof**	I	24	flat roof	24
	intermediate roof	II	78	intermediate roof	78
roof + facade	**intermediate roof + bordering structures**	III	34	intermediate roof/hollow concrete blocks	21
				intermediate roof/asbestos cement	6
				intermediate roof/slate	4
				intermediate roof/bargeboard	3
facade	**claddings**	IV	149	slate cladding	74
				asbestos cement cladding	34
				shingle cladding	31
				tarboard cladding	6
				sheet metal cladding	2
				synthetic matrial cladding	1
				corrugated iron cladding	1
	gaps + hollow spaces in the facade	V	75	hollow block	24
				half-timbering/wooden beam	22
				concrete gap	10
				at a window frame	6
				knothole (half-timbering)	5
				between house wall + wooden beam	3
				at a door frame	2
				behind metal boxes	1
				behind nest boxes	1
				wall crevice	1
	external blind case	VI	11	external blind case	11
	bargeboard	VII	4	bargeboard	4
	shutters	VIII	3	shutters	3
	Total				**378**

facades, or in crevices in the walls. The common pipistrelle used a wider range of roosts, which had their main emphasis in the building's cladding (see figure 32), but were also found frequently in the attic (see figure 30, figure 31 and table 11). One of the common pipistrelle's roosts was situated in an expansion joint of a flat roof and could be seen from below (see figure 33). It was striking that common pipistrelles were found relatively often in hollow concrete blocks of non-plastered walls. (For the most frequent roost type in the roost category: 'crevices and hollow spaces in the facade' see table 11.) In one case, a maternity roost colony even moved into stored hollow concrete blocks, which later on were integrated into the building in such a way that the common pipistrelle could enter and emerge through a gap. This roost has since then been selected every year by common pipistrelles.

Additionally, the potential roost offer in the project area was checked by comparing those buildings having roosts (roost buildings) with randomly selected buildings in selected villages. To this aim, a survey of the randomly selected buildings and roost buildings was carried out to investigate the character of maternity roosts of the common pipistrelle. The biggest towns (Marburg, Biedenkopf, Gladenbach, Wetter, Kirchhain, Stadtallendorf, Neustadt and Bad Endbach) were not considered in the selection. Twenty-two villages were randomly

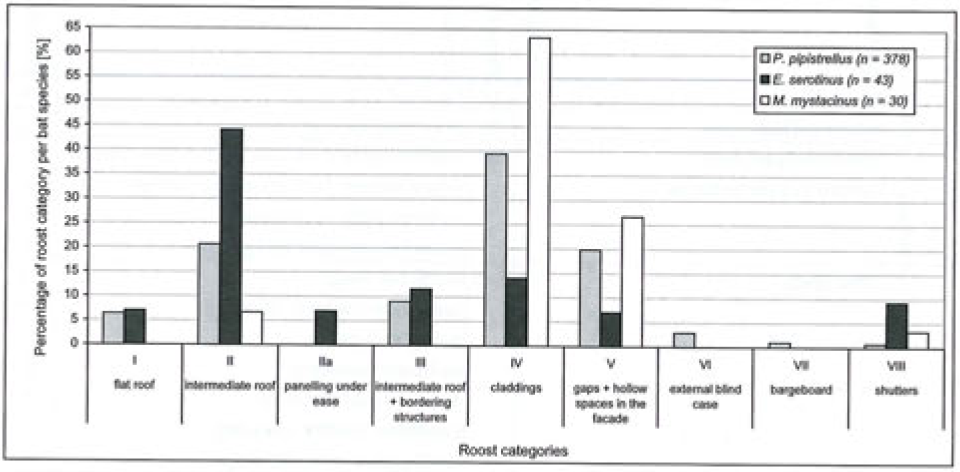

Figure 30: Comparison of the roost types of common pipistrelle, serotine bat and whiskered bat, of roosts known within the project, according to 8 roost categories.

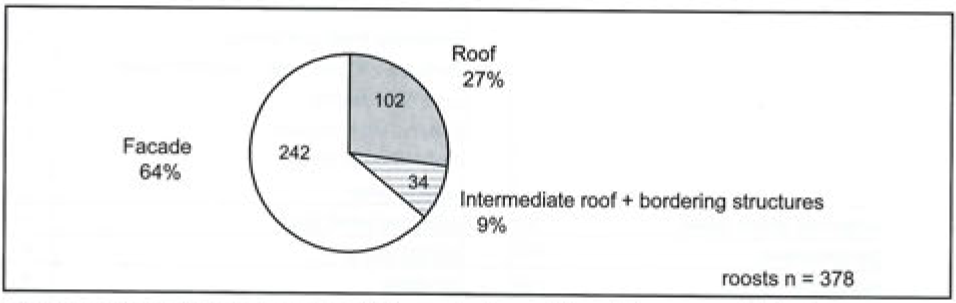

Figure 31: Distribution of categories of higher order for roost types for common pipistrelle roosts.

Figure 32: Maternity roost of the common pipistrelle behind an asbestos cement cladding. The entrance gap is situated below the window sill.

Figure 33: Maternity roost of the common pipistrelle in a concrete gap (expansion gap) of a flat roof.

selected from the remaining villages in the district. In these villages 30 % of buildings were randomly selected using a CD-ROM phone directory. For these randomly selected buildings, the corresponding structural parameters were recorded if possible (see table 9). More of the random buildings had external wall-cladding (approximately 60 %) and less flat roofs, intermediate roofs or any other crevices in the facade than the houses with roosts (see figure 34).

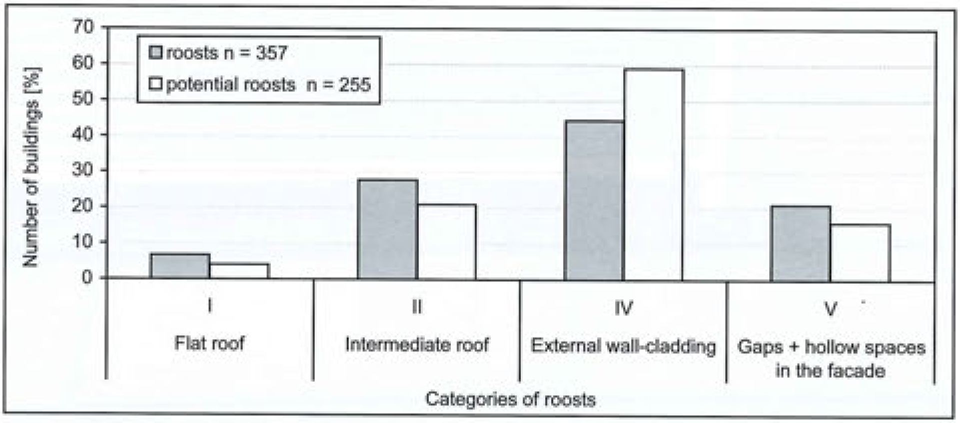

Figure 34: Comparison between roosts of the common pipistrelle and potential roosts at randomly selected buildings (for roost categories compare table 11).

JENKINS et al. (1998) compared 21 roosts of soprano pipistrelles (55 kHz type) and their surroundings, with 17 randomly selected houses in the northeast of Scotland (size of the investigation area 300 km^2). The roost houses and randomly selected houses did not differ siginificantly concerning structure (e. g. roof-material, age of house, heating capacity, wall-material, etc.). A difference could be detected only in the buildings' surroundings. In a study on the common long-eared bat by ENTWISTE et al. (1997), however, a difference between roost buildings and randomly selected buildings was found. The roost buildings were older, had divided attics, and were made of rough timber.

Bibliographical references

The largest percentage of the common pipistrelle roosts described in the literature was located behind house wall-cladding and in the facade (50 %) or in the intermediate roof (39 %) (see figure 35). The roosts found in the project area, have an even more clear emphasis on house wall-cladding or in hollow spaces of the facade (60 %), as half-timbered houses with slate facades are dominant in the project area.

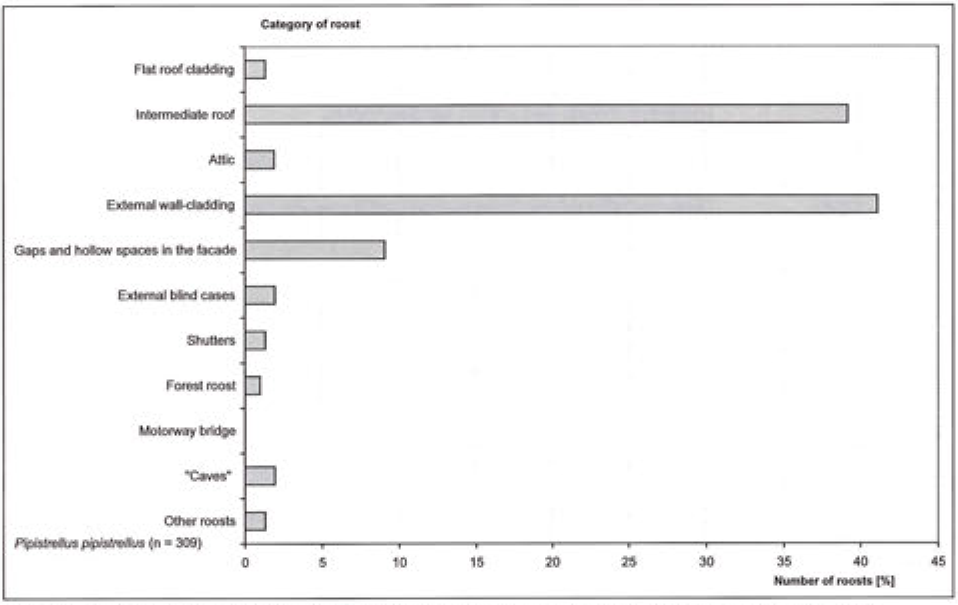

Figure 35: Literature describing roosts of the common pipistrelle (for bibliography see table 12).

Table 12: Bibliographical references to roosts of the common pipistrelle.

Source	**Maternity roosts**
EICHSTÄDT & BASSUS (1995)	the majority in the village or in bat roosting-boxes; few tree roosts (crevices in dead, damaged or very old trees
GODMANN (1994)	behind exterior wall cladding and in external blind cases in new and old buildings; under tin roofing on flat roofs
GODMANN (1996)	in crevices and niches in building facades; exterior wall cladding (slates, timber, sheet metal); external blind cases; loose plaster; in small rooms made of non-plastered hollow concrete blocks
GRIMMBERGER & BORK (1978)	behind timber panelling, in crevices in the exterior wall above windows, in attics behind timber panelling, behind external timber sheathing
HAENSEL (1992)	roofs, external blind cases, in hollow walls, intermediate ceilings, door pannels
HERMANNS & POMMERANZ (1999)	on buildings made of concrete slabs; under window sills
HIEBSCH (1983)	behind timber panelling; in crevices in brickwork; between timber planks (in half-timbered houses); in nesting boxes for birds and bats; tree hollows
HURKA (1966)	maternity colonies above window frames, behind two coat of arms mounted on the wall
JANSEN (1993)	behind wall timbering or ornamental edging; in cracks in old buildings; in the apexes of facades; hollow spaces under concrete
LABES & KÖHLER (1987)	behind cladding, in the hollow spaces between walls

Tab. 12: Continuation

Source	Maternity roosts
LANG (1996)	between roofing tiles and on window frames
MAIER (1992)	eaves of a brick house, behind a company name-plate
MAINER (1991)	external blind cases; intermediate roof (between slate and inner roof sheeting on gable; between boards and roofing fabric), behind lime plastering; in hollow concrete blocks on chimney
NATUSCHKE (1960)	behind window shutters, in brick hollow wall, narrow crevices under cardboard roofs, under attic flooring
OHLENDORF (1983)	behind timber planking, entrance slit between window blind and timber sheathing, timber-cladded wall pillars, slate hanging
RACKOW (1994)	in intermediate roofs (of glass wool with tar roofing paper on top, tar roofing paper only or timber sheeting with tar roofing paper)
SCHMIDT (1980)	shed roofs, window boxes, house attics, house roofs, bat roosting-boxes
STUTZ & HAFFNER (1985)	crevice roosts in and on buildings, mainly hollow spaces in intermediate roof (n = 107, 42 %) and behind wall sheeting (n = 107, 41 %)
SWIFT (1980)	attics and hollow spaces in walls
UNRUH (2001)	behind wood lagging, behind window shutters, under roof ridge
WAGNER (1987)	slate cladding; window shutters; timber sheeting; panelled area under eaves, hollow concrete blocks
	Individual roosts
SCHOBER & GRIMMBERGER (1998)	common pipistrelle roosts in crevices with access from outside, behind timber sheeting, wall cladding, window shutters, on half-timbered houses, also in narrow bat boxes. Individual bats in tiny wall crevices, behind company name plates, also occupy suitable new buildings
	Male roosts
GERELL & LUNDBERG (1985), GODMANN (1994)	bat boxes
HERMANNS & POMMERANZ (1999)	in buildings made of concrete slabs: under window sills, behind timber sheeting
LABES & KÖHLER (1987)	behind hymn number display boards in churches, tree hollows
NATUSCHKE (1960)	solitary males behind bark, window shutters, timber company signs
OHLENDORF (1983)	behind window shutters
WAGNER (1987)	window shutters; intermediate ceiling of an old cellar

5.2.2 Serotine bat

The serotine bat mainly uses roosts in the attic area, while 45 % of the roosts are situated in the intermediate roof, 7 % below flat roofs, 7 % in panelling under ease and a further 12 % in intermediate roofs and adjacent structures (see figure 30). Figure 36 shows a typical maternity roost of the serotine bat in the intermediate roof of a house. House cladding (13 %) and crevices in facades (7 %) are used for roosts much less. Compared to all other roost types, serotine bats were found behind shutters strikingly often (10 %).

Figure 36: Typical maternity roost of the serotine bat in an intermediate roof.

Bibliographical references

According to the literature, the serotine bat clearly prefers attics for roosting (52 %), followed by shutters with 13 % of the roosts (see figure 37). Intermediate roofs seem to play a subordinate role.

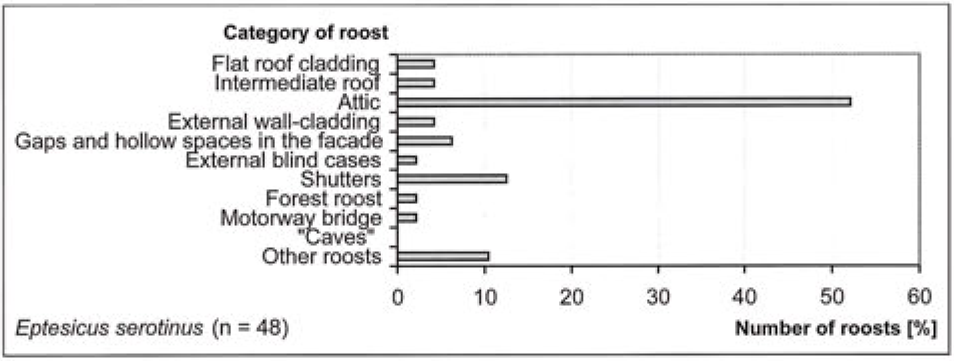

Figure 37: Literature describing roosts of the serotine bat (for bibliography see table 13).

Table 13: Bibliographical references to roosts of the serotine bat.

Source	Maternity roosts
CATTO et al. (1996)	in attics, in hollow walls
DIEHL (1994), SCHMIDT (1980), GLAS (1981)	attics
HAENSEL (1994), HAENSEL (1992)	5 of 7 roosts in attics – between the two upper roof battens and the strongly arched roof ridge tiles, two behind wall panelling and in the timber-panelled area under eaves of an overhanging roof, in the wide timber-panelled eaves of a slate tiled roof
HAVEKOST (1960)	attics, preferably those under tiled roofs – here under the arched ridge roofing tiles on the upper roof battens; in the connections between rafters, gable hollow wall
HIEBSCH & HEIDECKE (1987)	spacious, warm attics of old buildings, behind window shutters, under
HORÁČEK (1981)	exterior blind cases
DEGN (1983)	under the roof, behind timber wall sheathing
GOTTSCHALK (2000)	attic, cracks in a wall, intermediate wall, cladding, roosting boxes, window shutters
LABES (1990)	in the (roof) ridge end tile near or above the end of the ridge beam
MAINER (1991)	between the inner roof framework and the roofing tiles; false floors
MESCHEDE & HELLER (2000)	trees play only a minor role as roosts for colonies, but could play a greater role as roosts for solitary males
NATUSCHKE (1960)	under the roof ridge tiles, between timber sheathing and sheet metal lining
STRATMANN (1979)	in attics (84 %) or behind window shutters (9.5 %)
STRATMANN (1980)	in the channels/grooves of the roof ridge, under thin roof lining or behind window shutters
WAGNER (1987)	attics, under roofing tiles over the gable of an exterior house wall; the panelled area under the eaves of a house; window shutters
WEIDNER (1995)	roosts on the beams of a dormer window, hanging freely on the wall under a dormer window
	Individual and male roosts
HAVEKOST (1960)	in attics, in a role of roofing felt outside, behind window shutters
HEISE (1983)	roosts in bat roosting boxes
NATUSCHKE (1960)	behind window shutters

5.2.3 Greater mouse-eared bat

Three maternity roosts of the greater mouse-eared bat, located in attics, were already known. The animals were hanging freely from the roof beams, sitting in peg holes or were found between inner wainscoting and the attic. One peculiarity was a big hollow space in a wall of a church attic, into which the whole colony disappeared at times. Outside the project area, a new maternity roost was found in a nest box.

Bibliographical references

Nearly 60 % of the Greater mouse-eared bat roosts are situated in attics, according to literature (see figure 38 and figure 39). All other roost types are less significant.

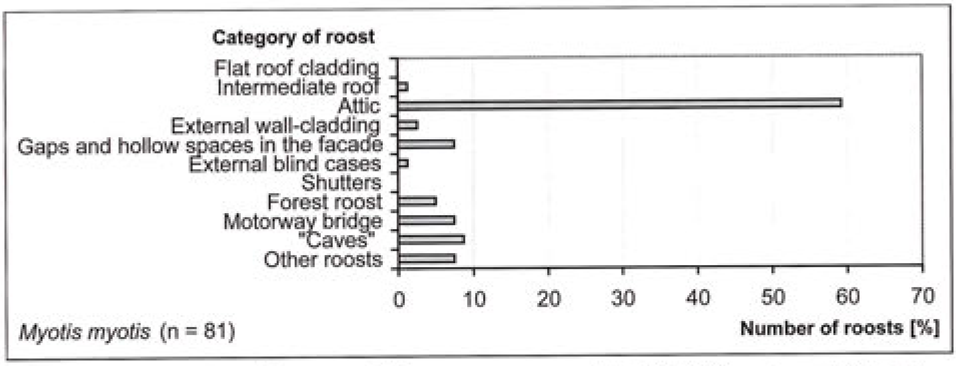

Figure 38: Literature describing roosts of the greater mouse-eared bat (for bibliography see table 14).

Figure 39: The maternity roost of greater mouse-eared bats in an attic.

Table 14: Bibliographical references to roosts of the greater mouse-eared bat.

Source	**Maternity roosts**
Albrecht & Bekker (2001)	in a large hall in a gap between cement blocks and exterior wall
Bilo (1990)	roof truss, hanging places between rafters, fire places, peak of dormer window on roof terrace doorway
Gebhard & Ott (1985)	attic
Gebhard (1997)	maternity roost of greater mouse-eared bats in a heated cellar room (Baden-Württemberg)
Haensel (1974)	attics, in a shaft where heating pipes ran along the upper end
Heddergott (1992)	attics, occasionally also in the panelled area under the eaves and in false floors, behind timber framework on inner gable wall
Heddergott (1994)	attics, in the space between two connected houses (emergence via ventilation pipe), in a bricked-up, disused circular staircase (emergence via hole in the attic and from here to outside), behind the timber sheathing on a half-timbered wall, in false floor of a large, unused sheet metal cladded warehouse
Henkel et al. (1982)	attics, hollow space in an attic wall
Hiebsch & Heidecke (1987)	spacious attics of tall buildings, church attics, in a favoured cellar
Natuschke (1960)	domes of church onion towers, spacious attics, deep hole in wall of church tower
Oldenburg & Hackethal (1989)	church attics (hanging places: roof ridge of the chancel, tower wall inside the roof space of the nave, hollow spaces in beam heads, roof ridge of nave)
Roer (1988)	preference is for draught-free slate attics
Rogée & Lehmann (1994)	attics, tree hollows, bat roosting boxes, galleries and motorway bridges
Rudolph & Liegl (1990)	94.4 % (n = 126) of roosts free in roof trusses, these often spacious; frequently in small, narrow sectioned off areas or extensions of larger roof trusses; if the colonies are situated in church towers then frequently in the top of onion domed towers or domed towers covered with black slate tiles or with dark, oxidized copper; three cases in which small colonies were found in crevice roosts between two walls or between roofing tiles and the inner roof lining; unusual maternity roost types are sheds (in walls, hanging free under the roof), in the abutments of a motorway bridge (in spacious, hall-like concrete chambers), in a factory hall (on the cement ceiling and under a hollow concrete block wall), a tower made of sandstone block in a castle ruin
Schober & Grimmberger (1998)	in the north in warm attics, church towers. Temperatures up to 45 °C, rarely in warm subterraneous rooms; in the south in caves

Tab. 14: Continuation

Source	**Maternity roosts**
Schulze (1992)	attics, under the roof lining and between chimneys
Stratmann (1979)	94 % in attics, 0.2 % (one find) in exterior blind case
Zahn & Henatsch (1998)	open hanging places e.g. on roof beams, directly in the roof ridge
Zahn (1999)	roof trusses, tops of church towers, holes in church tower walls, hollow spaces in a concrete bridge
	Individual, male and intermediate roosts
Haensel (1974)	in the cellar of a former beer warehouse
Heck & Barz (2000)	hanging places in the abutment chambers in crevices in transitional constructions (between bridge and abutment, 40 cm high interconnected opening), in bat boxes, in abutments (hollow concrete constructions) free hanging places and inside round vapour seal vents inserted into the ceiling (diameter 10–12 cm)
Heddergott (1994)	predominantly in attics, but also wall panelling, false floors, hollow concrete blocks
Hiebsch & Heidecke (1987)	sandstone caves, spacious cellars, lime kilns, stone bridges, attics, exterior blind cases, window shutters, bird boxes and bat boxes
Koettnitz & Heuser (1994)	roosts in 18 motorway bridges (pre-stressed concrete box girder construction)
Nagel & Nagel (1988)	bat boxes
Natuschke (1960)	individuals in beam holes in attics, in crevices in the stonework under bridges, in gateways and stone quarries
Rudolph & Liegl (1990)	for the most part crevice roosts (beam grooves, crevices in roof ridge etc) in attics, more rarely in wall niches, in hollow concrete blocks of sheds or in crevices in the rock of natural caves
Schober & Grimmberger (1998)	individual bats also in nest boxes and tree hollows

5.2.4 Natterer's bat

Of eleven Natterer's bat roosts located in the project area, six were found in hollow concrete blocks (see table 15). Natterer's bats could be observed hanging in the hollow space in a cowshed's ceiling (see figure 40). The spatial proximity to cowsheds was remarkable: six of the roosts were located in or in close proximity to a cowshed.

Table 15: Maternity roosts of the Natterer's bat within the project area.

Roost type	Spatial proximity to cowshed
Slate cladding of a dwelling house	Next to cowshed
Timber framing outside	No cowshed close-by
Hollow concrete block in a barn	Above cowshed
Intermediate roof	No cowshed close-by
Hollow concrete block outside	No cowshed close-by
Hollow concrete block outside	At a sty
Hollow concrete ceiling (pipe)	Inside a cowshed
Hollow concrete ceiling	Inside a cowshed
Hollow concrete block outside	Ancient barn
Ridge beam of a church attic	Next to cowshed
Intermediate roof/panelling under ease	Next to cowshed

Figure 40: Cowshed which is permanently occupied by cows, with a big maternity roost of the Natterer's bat located in the pumice stone ceiling.

Bibliographical references

According to the literature, 34 % of the Natterer's bat roosts were found in the woods, followed by 32 % in attics (see figure 41). Crevices and hollow spaces in the facade only count for 20 %. However, in the project area, all roosts except one could be found in hollow spaces (though not only on facades) (see table 15).

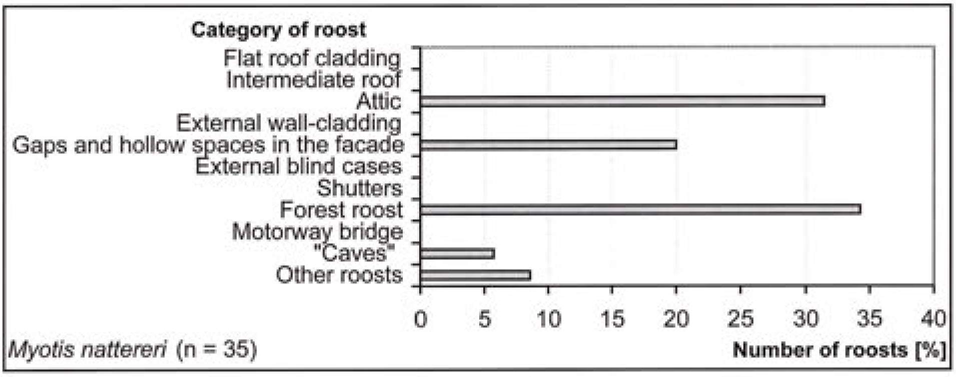

Figure 41: Literature describing roosts of the Natterer's bat (for bibliography see table 16).

Table 16: Bibliographical references to roosts of the Natterer's bat.

Source	**Maternity roosts**
Böhme & Natuschke (1967)	narrow, approx. 4 m long hollow spaces under the cladding on a horizontal ceiling beam in the attic storey
Buchen (1991)	lightly plastered side of gable, holes and crevices in pumice stone hollow concrete bricks; remained intact even after application of slate hanging
Cervený & Horáček (1981)	roosts in tree hollows, caves, crevices in interior walls of buildings, cracks in timber in attics; maternity roosts: branch cavity of a chestnut tree, hole in the wall of a church attic (both also hibernacula)
Geisler & Dietz (1999)	peg holes in the (attic) beaming
Hiebsch & Heidecke (1987)	bird nesting boxes, tree hollows, spaces in half-timbering, behind timber sheeting in an attic
Jansen (1993)	hollow space in a building made of basalt
Jones et al. (1996)	maternity roosts almost always in buildings, individual bats in bat boxes
König & König (1995), Labes & Köhler (1987), Park et al. (1998)	bat boxes
Limpens & Bongers (1991)	in woodpecker holes
Siemers et al. (1999)	nest boxes, branch cavity of a beech
Swift (1997)	in a bridge, attics – all in crevices with the exception of one (in roof ridge, normally between stones or between stone walls and roof beams)
	Intermediate and individual roosts
Cervený & Horáček (1981)	solitary roosts only in subterranean locations

Tab. 16: Continuation

	Intermediate and individual roosts
HIEBSCH & HEIDECKE (1987)	intermediate roosts in rock crevices and cracks, also holes in walls above and below ground
SCHOBER & GRIMMBERGER (1998)	summer roosts in tree hollows and bat roosting boxes in the forest, also in crevices in and on buildings (roof truss, more rarely in roof ridge), individual bats also under bridges, behind window shutters

5.2.5 Whiskered bat

The whiskered bat mainly uses house sidings (63 %, 19 of 30 roosts) as roosts (see table 17). The greatest proportion of facade sidings have slate cladding, namely 14 out of 19 roosts (see figure 42).

Table 17: Roost types of the whiskered bat within the project area.

Roost type	**Number**
Intermediate roof	2
Slate cladding	14
Asbestos cement cladding	2
Shingle cladding	2
Sheet metal cladding	1
Timber framing/wooden beam	4
Knothole (timber framing)	1
Hollow block	2
Behind junction box	1
Shutters	1
Total	**30**

Bibliographical references

According to our findings, many of the whiskered bat roosts were situated behind house sidings. Nevertheless, many roosts were also found in crevices in the facade and in attics (see figure 44). But there might also be intermediate roosts included in the classification `attic´, as some of the references did not distinguish these features clearly.

Figure 42:
Maternity roost of the whiskered bat behind a slate siding.

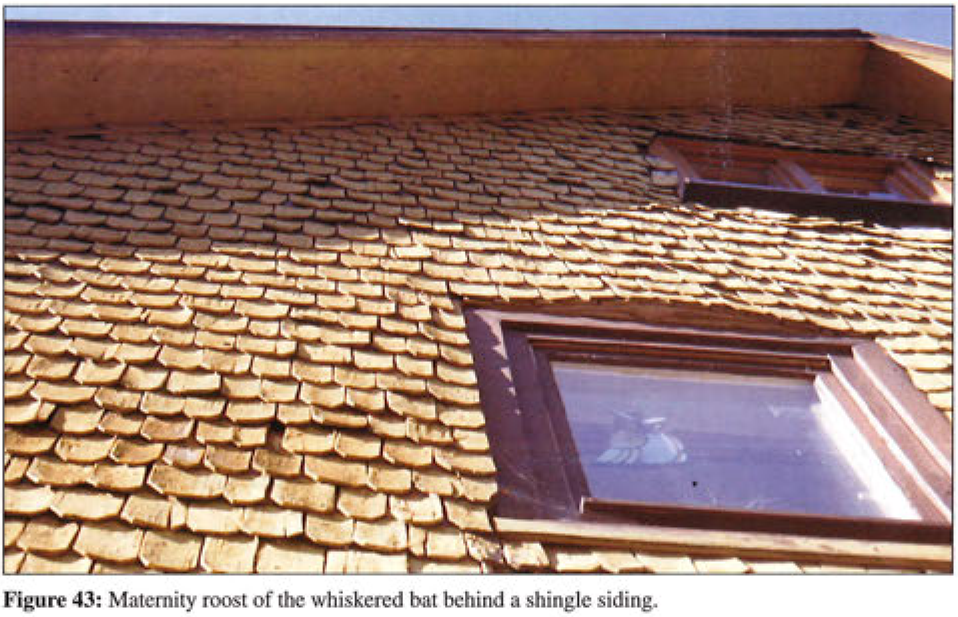

Figure 43: Maternity roost of the whiskered bat behind a shingle siding.

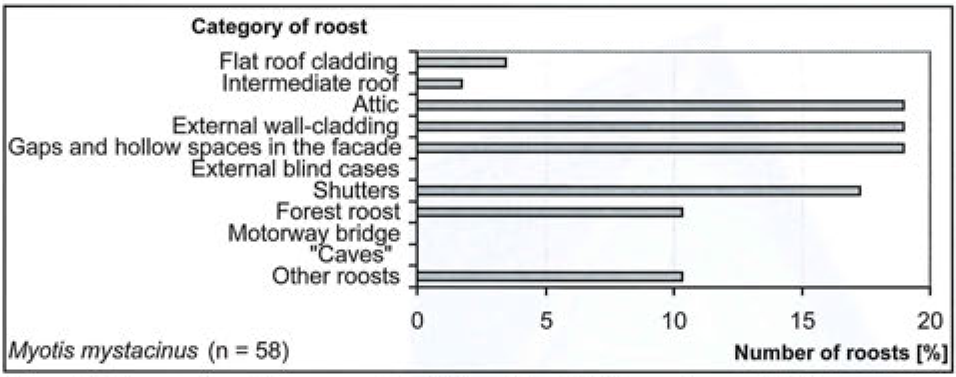

Figure 44: Literature describing roosts of the whiskered bat (for bibliography see table 18).

Table 18: Bibliographical references to roosts of the whiskered bat.

Source	**Maternity roosts**
Franke (1997)	up to 80 % in man-made structures: external part of buildings (timber framing in walls of attics above blocks of flats, behind corner boards, in timber framing in walls behind window boards, behind exterior wall cladding, between wall beams and timber sheeting, outlet, corners of roof beaming, between stone wall and beams, in attics (between roof beams and roof, metal covered chimney, between roof rafters and roof), in crevice-type spaces between insulation (30 – 60 cm thick) and house wall, in flat bat boxes
Hiebsch & Heidecke (1987)	exclusively in and on buildings, behind window shutters, flat gaps behind company name plates and timber sheathing, occasionally in attics
Holzhaider & Zahn (2001)	cracks and crevices, crevices behind roof beams and behind window shutters
Jones et al. (1996)	maternity roosts almost always in buildings, individual bats in bat roosting boxes
Mainer (1991), Ohlendorf (1982)	behind window shutters
Natuschke (1960), Kraus & Gauckler (1972)	behind window shutters
Rindle & Zahn (1997)	roosts in roof truss – between roofing sheet metal and the boards beneath it, behind wind boards of house gables of two residential buildings situated one behind the other
Schmidt (1980)	window shutters, timber sheathing, bat roosting boxes
Taake (1984)	slate cladding, 7 attics, 2 under plastic edging on a garage roof
Thompson (1979)	in a hollow stone wall, behind a large wooden sign (cladding)

Tab. 18: Continuation

	Individual Roosts
RICHARZ (1994)	crevice dwellers in and on buildings, in tree hollows and tree crevices, also bat boxes
SCHOBER & GRIMMBERGER (1998)	roosts mostly in buildings in narrow crevices with outside access, between beams and masonry, behind window shutters, rarely in nest boxes

5.2.6 Common long-eared bat

Within the project area four maternity roosts of the common long-eared bat were found in attics, one in a hollow concrete block and a further one in the intermediate roof of a building.

Bibliographical references

According to the literature, more than half of the roosts of the common long-eared bat are located in the forest and 22 % of the roosts are found in attics (see figure 45).

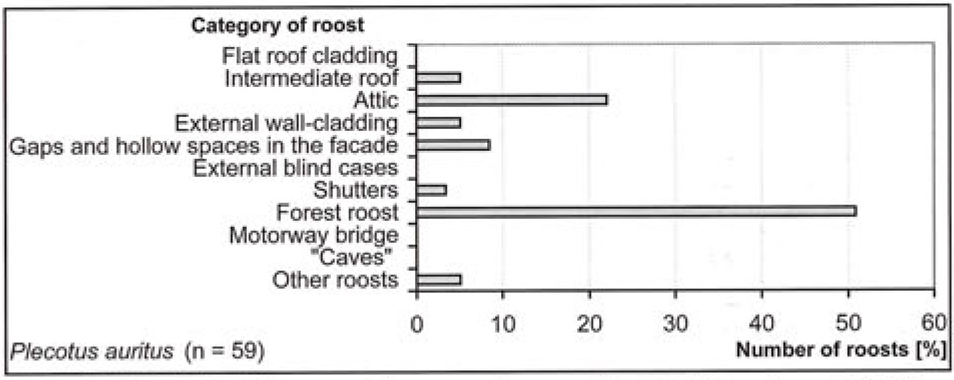

Figure 45: Literature describing roosts of the common long-eared bat (for bibliography see table 19).

Table 19: Bibliographical references to roosts of the common long-eared bat

Source	**Maternity roost**
Battersby (1999)	in old buildings, predominantly in the apex of roofs
Boyd & Stebbings (1989), Dieterich (1988), Heise & Schmidt (1988), Park et al. (1998), Schwarting (1994)	bat boxes
Entwistle et al. (1997), Speakman et al. (1991)	attics (in the apex of the attic space)
Fuhrmann & Godmann (1994)	16 tree roosts (pine, beech, oak) under roofing felt of a (timber) shelter
Haensel (1992)	spacious attic, in ridge between upper connecting roof laths and terminating roof tile
Hiebsch (1983)	large attics (hanging places hidden in roof timbers and between planking), behind exterior wall cladding
Jones et al. (1996)	almost exclusively in buildings, single specimen in bat boxes
Labes & Köhler (1987)	in bat boxes, in church towers
Limpens & Bongers (1991)	in woodpecker holes, in houses
Mainer (1991)	bat boxes, in attic space hanging freely on beams or in bung holes, between beams and masonry, stairs to attic space, behind a beam, between slate and inner roof sheeting, behind external wood lagging, in hollow bricks
Natuschke (1960)	in attics
Richarz (1994)	tree hollows, bird boxes, crevices in and on buildings
Wagner (1987)	attics, roof truss
	Individual and male roosts
Natuschke (1960)	solitary males in attics and in bird boxes
Schober & Grimmberger (1998)	summer roosts: in tree hollows, bat boxes and bird boxes, in attics. Individual bats also in rock caves, behind window shutters, crevices on buildings
Many different authors were citedin: Meschede & Heller (2000)	regularly in attics of churches or sheds (behind beams, niches in beam grooves and peg holes; between roofing tiles and behind timber sheeting, seldom free hanging), natural roosts in tree hollows, sometimes behind loose bark; evidence in forests mostly in boxes, also tree hollows and tree crevices

5.2.7 Grey long-eared bat

In the project area were found 6 crevice roosts (three behind a siding, two in an intermediate roof and another crevice roost), and four roosts in attics.

Bibliographical references

According to the literature, the roosts of the grey long-eared bat are most frequently situated in attics (46 % of the roosts) (see figure 46).

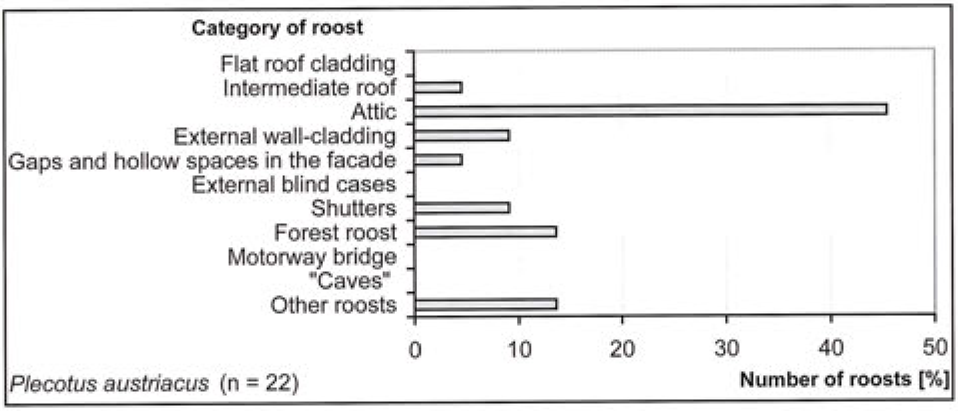

Figure 46: Literature describing roosts of the grey long-eared bat (for bibliography see table 20).

Table 20: Bibliographical references to roosts of the grey long-eared bat.

Source	Maternity roosts
Fuhrmann & Godmann (1994)	roosts exclusively in attics
Handtke (1967)	connection fissure of a central pillar in the nave attic of a church; between roof ridge and a covering board
Hiebsch & Heidecke (1987)	spacious attics; hanging places hidden under the roof ridge tiles, between planking, in hollow spaces in the roof timbers, often near the chimney; prefer to fly in through larger entrances such as windows and skylights
Kiefer & Veith (1998)	attic (hanging freely in roof ridge or above apse, occasionally in hidden places
Limpens & Bongers (1991)	in woodpecker holes in old trees, in houses
Piechocki (1966), Wagner (1987)	attic
Schober & Grimmberger (1998)	in buildings, sometimes hanging freely in roof ridge, sometimes hidden in beam grooves

Tab. 20: Continuation

Many different authors were cited in: MESCHEDE & HELLER (2000)	maternity roosts exclusively in buildings (mostly in ridge of roof truss; beam grooves, hollow spaces in walls
	Individual roosts
SCHOBER & GRIMMBERGER (1998)	individual bats also in caves

5.2.8 Barbastelle bat

In the project area, the barbastelle bats use a slate siding with some tiles missing of a big residential building (see figure 47). In addition, parts of the colony could from time to time be found behind a metal siding of a neighbouring building.

Figure 47:
Maternity roost of the barbastelle bat behind a slate facade.

Bibliographical references

According to the literature, roosts of the barbastelle bat are mostly in the forest (75 %) (see figure 48).

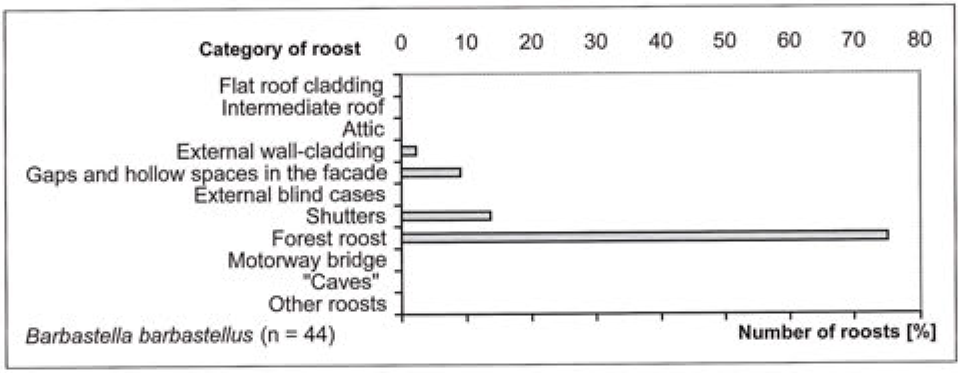

Figure 48: Literature describing roosts of the barbastelle bat (for bibliography see table 21).

Table 21: Bibliographical references to roosts of the barbastelle bat.

Source	**Maternity roosts**
HEDDERGOTT (1992a)	behind the timber sheeting of a house
NATUSCHKE (1960), TRESS et al. (1988), HIEBSCH & HEIDECKE (1987), SPITZENBERGER (1993)	behind shutters
PODANY (1995)	in tree hollows
RICHARZ (1989)	hollow space between wind board and roof; evidence almost exclusively in crevice-type hiding places on buildings, maternity colonies almost always behind window shutters
RICHARZ (1994)	roosts in and on buildings and in tree hollows
SPITZENBERGER (1993)	behind wooden border of a timber shed (n = 10), behind wooden border on roof (n = 1), in bat roosting boxes (n = 3), in hollow bricks (n = 1)
STEINHAUSER (2002)	29 of 32 roosts behind loose bark (pines, robinias, oaks)
	Individual and male roosts
HEDDERGOTT (1992a)	cracks in wall
SCHOBER & GRIMMBERGER (1998)	roosts in crevices on buildings, frequently behind window shutters, tree hollows, nesting boxes or cave entrances
SIERRO (1999)	shelter in crevices in rocks or in trees
SPITZENBERGER (1993)	roosts in buildings (roof truss, fire place or on external wall), wall above open underground train station

5.3 Exposition

The roost's exposition is of prime importance for the temperature in the roost. Especially for pregnant and suckling females which have a high metabolism, and seldom fall into torpor during the day, an optimal ambient temperature is important (compare RACEY 1969, RACEY 1973c).

Common pipistrelle

Most of the common pipistrelle roosts (18.2 %) had a southerly exposure (see figure 49). However, the directions west, southwest and east were also preferred expositions and counted for 56.5 % of all roosts.

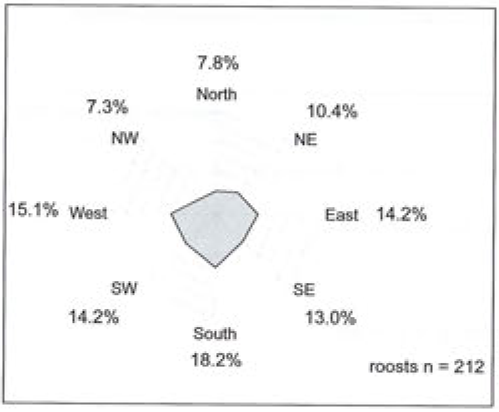

Figure 49:
Percentual distribution of expositions of 212 common pipistrelle roosts in the project area.

HERMANNS & POMMERANZ (1999) examined different common pipistrelle roosts in Rostock (in buildings made with precast concrete slabs, in slab crevices, below window sills, in a roof with air insulation, and behind a timber framework). Their results revealed an even more evident preference for southerly-exposed roosts, namely 50 %. A further 35 % of the roosts had a westerly exposure. THOMPSON (1977) investigated common pipistrelle roosts in England (45 kHz and 55 kHz types), which favoured roosts facing south, southeast, and southwest (see figure 50).

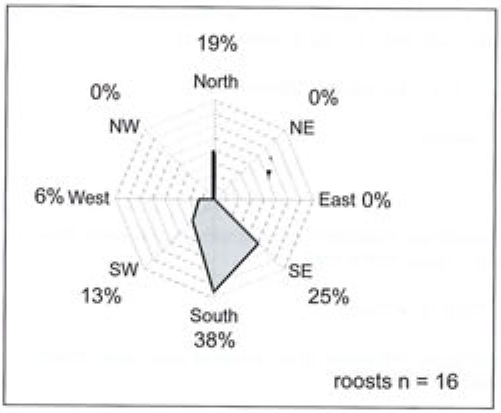

Figure 50:
Percentual distribution of exposition of common pipistrelle roosts (45 kHz and 55 kHz types), in an investigation by THOMPSON (1977) in England.

Newly created potential common pipistrelle roosts

The crevice roosts created within the project's framework, potentially suitable for common pipistrelles, had mainly south and southeast expositions (see figure 51). However, especially for common pipistrelles, which switch their roosts frequently (compare chapter 7.2.) it can be assumed that a wide range of directions is important.

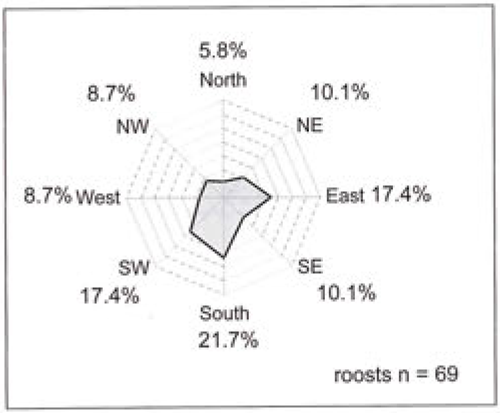

Figure 51:
Percentual distribution of exposition of created crevice roosts within the project's framework.

Serotine bat

The serotine bats in the project area used more southerly exposed roosts (33.3 %) than the common pipistrelles (see figure 52). In addition, they used westerly exposed (16.7 %), south-westerly and south-easterly exposed roosts (both 11 %). 12.2 % of the roosts had a northerly exposure.

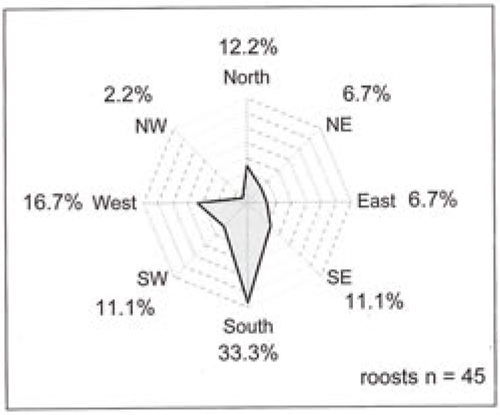

Figure 52:
Percentual distribution of exposition of 45 serotine bat roosts in the project area.

Example of a roost assemblage of serotine bats at the psychology-building in Marburg

Fifty-five of the 123 window gaps on the western, southern, and eastern sides of the building were used as summer roosts by serotine bats in 1999. Of these, 31 were used as maternity roosts (n ≥ 2 individuals) and 24 as individual roosts.

There were clear differences in the use of three of the sides of the building (see table 22). The maternity roosts are almost exclusively situated on the southern side (45.2 %) and western side (41.9 %) of the building. In contrast, most of the individual roosts were located on the eastern side (54.2 %). In the maternity period, the females used the roosts with the highest temperatures.

Table 22: Number and proportion, on a percentage basis, of maternity roosts and individual roosts of the serotine bat, on the western, southern and eastern sides of the psychology-building in Marburg.

Number	Western side		Southern side		Eastern side		Total (100%)
Windows	36	29.3%	60	48.8%	27	21.9%	123
Roosts	16	29.1%	22	40%	17	30.9%	55
Maternity roosts	13	41.9%	14	45.2%	4	12.9%	31
Individual roosts	3	12.5%	8	33.3%	13	54.2%	24

BATTERSBY (1999) examined roosts of the serotine bat in Sussex. 40 % (n = 6) of the maternity roosts had a southerly or south-westerly exposure; only 135 (n = 2) had a northerly exposure. The temperature in the roost, during the bats' presence was 39.3 °C, the daily average temperature was 24.7 °C.

Whiskered bat

The whiskered bat reveals the clearest preference for southerly (28.6 %), south-westerly (21.4 %) and south-easterly (21.3 %) exposed roosts (see figure 53). The northern and north-easterly exposed roosts are avoided completely. NYHOLM (1965) also designated this species as one that likes warmth.

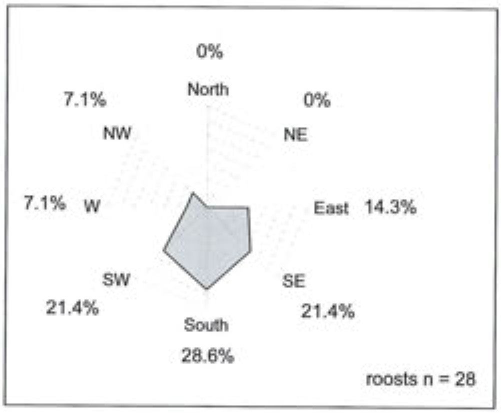

Figure 53:
Percentual distribution of roost expositions of the whiskered bat in the project area.

5.4 Roost openings

Common pipistrelle

A large part of the common pipistrelle's emergence gaps (n = 24) are situated 5 m to 7 m above ground-level (see figure 54). Possibly, the greatest number of potential roosts is found at this height. Additionally, the common pipistrelles need a minimum height while emerging, as they let themselves fall out of the roost (compare chapter 3.1.3 and chapter 6.5.4).

Serotine bat

The greater part of the serotine bat's roost openings (40 %) in the project area are 10 m to 12 m above ground-level, thus situated clearly higher than those of the common pipistrelle (see figure 54). Serotine bats prefer roosts near the roof (intermediate roof, flat roof), which are found at this height.

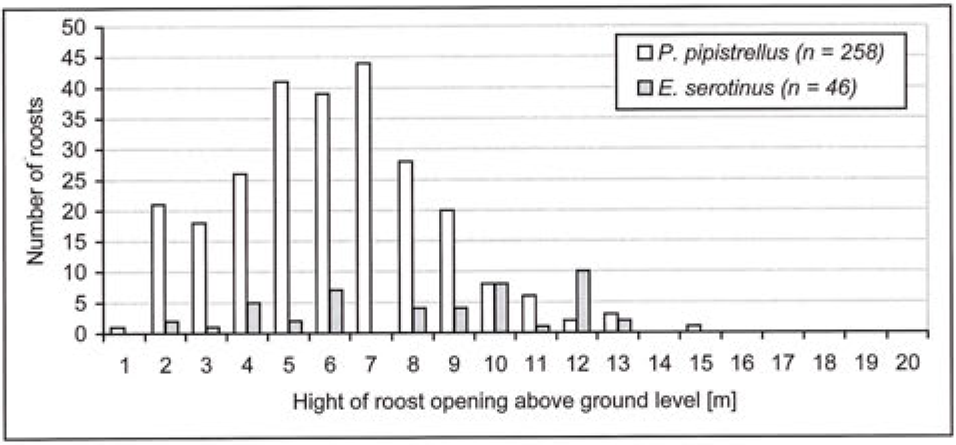

Figure 54: Comparison of the roost opening heights of the common pipistrelle and the serotine bat.

Comparing the height of roosts in the low mountain ranges (of the area of investigation) with roosts in the north of Germany (LOTHAR BACH, written statement), it is rebandable that the proportion of higher situated roosts increases with a greater offer of the same. In the low mountain range, 56 % of the roost openings are situated at 9 m or higher, whereas in the north of Germany roosts at this height account for 75 % (see figure 55).

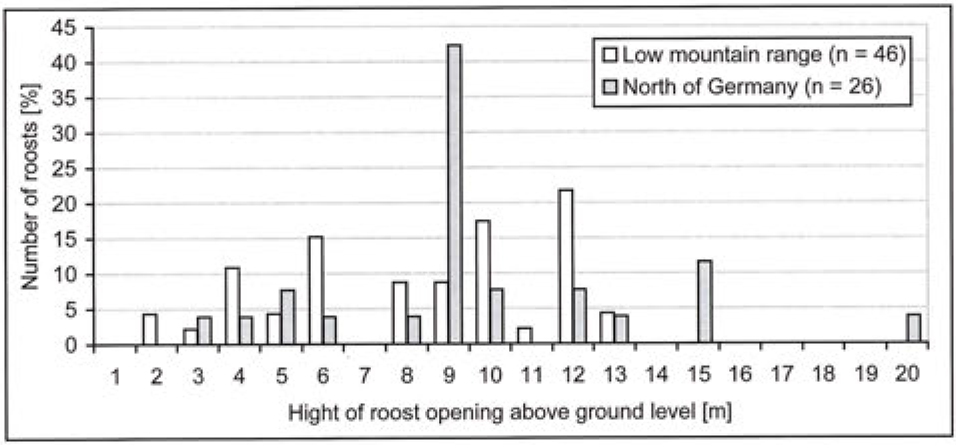

Figure 55: Height of serotine bat roost openings above ground level in the investigation area (low mountain range) and in the north of Germany.

5.5 Location of roosts in town

The 27 known maternity roosts of the common pipistrelle, as well as the four maternity roosts of the serotine bat, and two roosts of the grey long-eared bat in Kleinseelheim, are nearly all located in the old village centre (see figure 56). The 10 summer roosts of the serotine bat and two common pipistrelle roosts in Großseelheim are distributed in the same way (see figure 57).

To get an idea of how many buildings of a locality are used by bats, the number of buildings in individual villages was determined by means of aerial photographs and compared to the number of roost buildings.

The proportion of buildings with bat roosts in the villages which had been mapped several times varied between 3.2 % and 17.25 %(see figure 58). In those villages that were investigated intensively over several years, namely Gönnern, Wittelsberg und Kleinseelheim, the proportion of roost buildings was between 7.1 % and 17.2 %. These roosts were principally common pipistrelle roosts. As a tentative estimation, it can be supposed that in villages where a bat colony is known, about 10 % of the buildings have a roost. According to a survey carried out in a village in northern Scotland, bats were found in 23 % of the houses (PRITCHARD & MURPHY 1988).

In addition, the number of buildings inside and outside the old village centre was counted and compared to the respective number of roost buildings by means of aerial photographs. With one exception (Wittelsberg), most of the villages' roosts (80 %) are located inside the old village centre (see figure 59). The preference of the village centre in Eckelshausen becomes especially clear, where the number of buildings outside the town centre is twice as high as inside. In Wittelsberg, which has many common pipistrelle roosts, the distribution of roosts inside and outside the village centre corresponds to the offer of buildings. Especially common pipistrelles that had frequently been found in non-plastered hollow concrete block walls, are able to settle relatively quickly in new buildings as well.

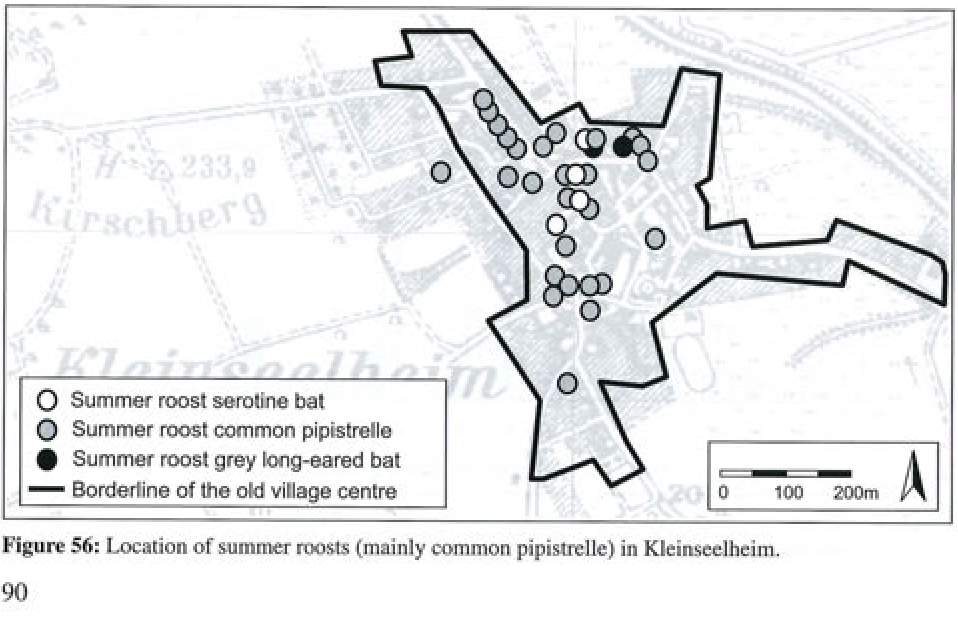

Figure 56: Location of summer roosts (mainly common pipistrelle) in Kleinseelheim.

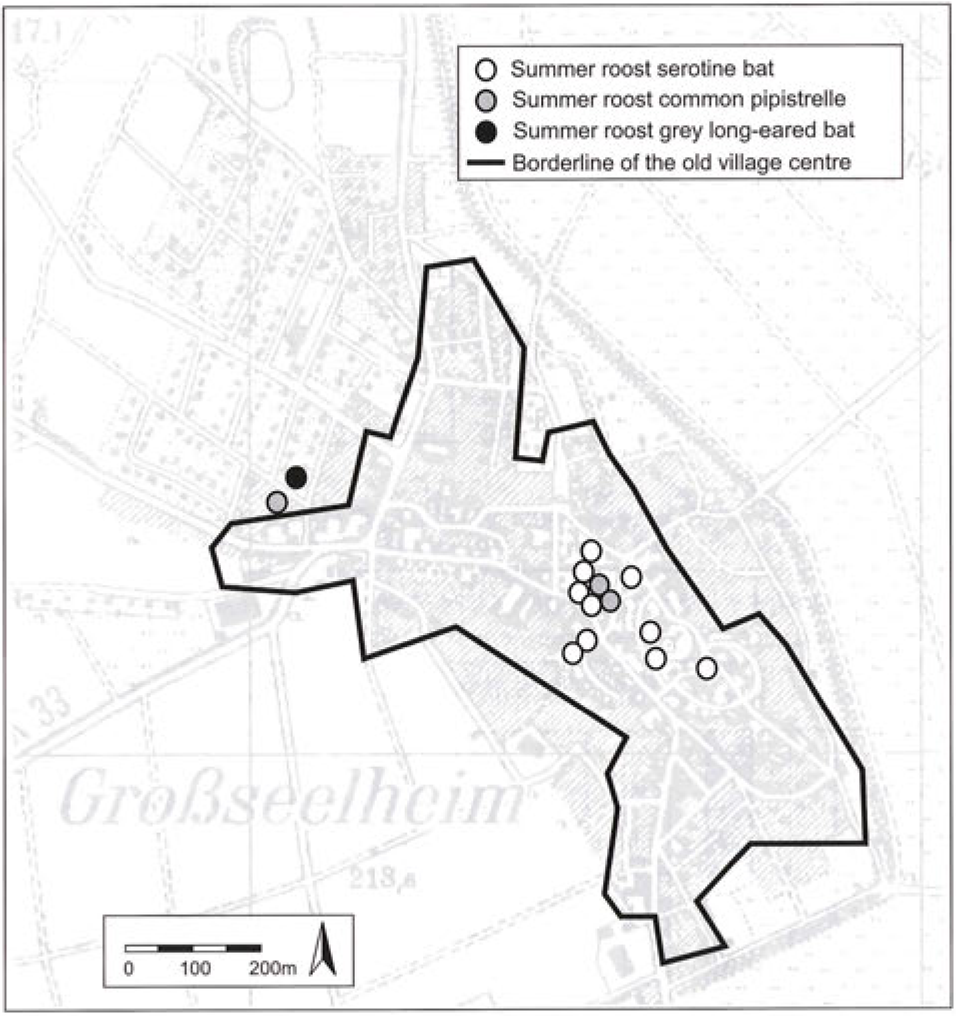

Figure 57: Location of summer roosts (mainly serotine bat) in Großseelheim in relation to the old village centre.

5.8 Height of buildings

The height of the buildings in which the common pipistrelles were located was determined through the number of floors. The common pipistrelles used the lower buildings over-proportionally, whereas the higher ones were mostly avoided (see figure 62).

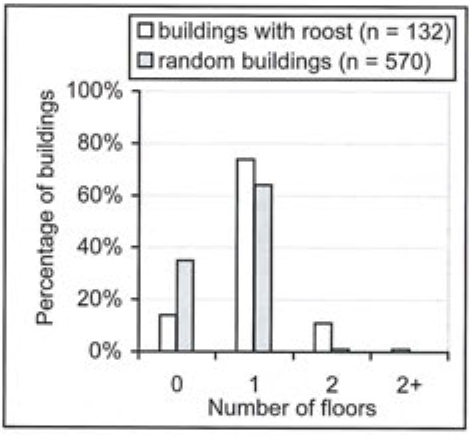

Figure 62:
Percentual proportion of common pipistrelle's roost buildings and random buildings with different number of floors.

5.9 Material of landing area

The material of the landing areas of most common pipistrelle's roosts consisted of plaster (mainly for intermediate roofs), followed by timber (sidings) and slate (sidings) (see figure 63). A rough material, which is the case with plaster, and also often with timber, is essential for a bat's landing area. Smooth slate, in comparison, is only adequate as landing area if it consists of single, accessible tiles onto which the bats can hold when they are landing, and then crawl into the roost.

5.10 Roost temperatures

A frequently mentioned feature for the choice of roosts by bats is the roost temperature (HAMILTON & BARCLAY 1994, WINCHELL & KUNZ 1996). Various factors indicate that the roost temperature is important for bats. The duration of pregnancy is determined significantly by the ambient temperature (AUDET & FENTON 1988, RACEY 1969, RACEY 1973c; RACEY & SWIFT 1981) and the development of the young also slows down with lower temperatures (AUDET 1990, HOYING & KUNZ 1998, TUTTLE & STEVENSON 1982). It is supposed that thermoregulatory advantages are responsible for the social behaviour of bats (KUNZ 1982) and that the cost of thermo-regulation is reduced through behaviours such as the forming of colonies and clusters, and the choice of roosts (TUTTLE 1975, cited in TUTTLE 1976 [*Myotis grisescens*]).

If the choice of roosts depends to a great extent on the temperature prevailing in the roost, then a better knowledge of these temperatures is important in order to get a better understanding of roost requirements. A typical feature of bat roosts, also of crevice roosts, at buildings is that they are spacious. This allows the animals to pick areas within the roost which have different temperatures. Furthermore, the crevice roosts are mostly difficult to access from outside. These characteristics lead to the problem that a temperature measurement can

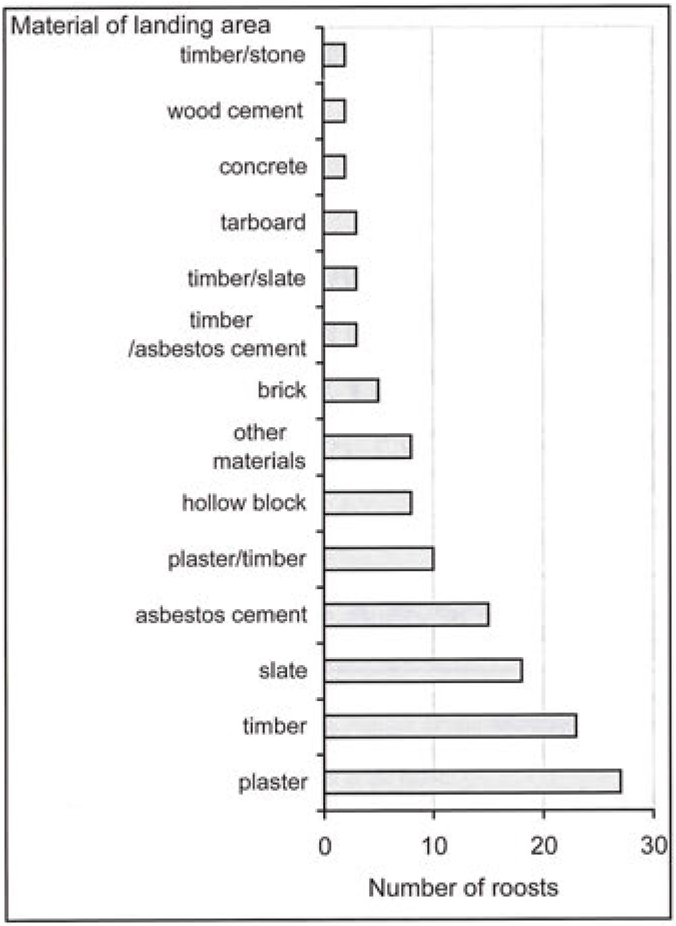

Figure 63: Material of the landing areas of common pipistrelle roosts (n = 129).

be carried out only insufficiently. In spite of this, the temperature of different roost types was determined, in order to have examples to demonstrate the different specific properties concerning the course of temperatures and heat capacity.

5.10.1 Hollow spaces in the facade and behind facade siding

Hollow spaces at or in facades and behind facade sidings constitute a frequently used roost type for house-dwelling bat species.

Maternity roost of the common pipistrelle

The course of temperature in a maternity roost of the common pipistrelle behind an easterly exposed slate siding is represented in figure 64. The animals used the roost during the represented year at the beginning of July, when the measured maximum roost temperature was between 25 and 35 °C. On sunny days, the roost was heated intensively, and the nightly temperature in the roost remained at 20 °C, despite lower outside temperatures (beginning of same common pipistrelle colony. This correlation could be proved by means of recaptures in the years 1998 and 1999. For example, trapping in 1998 revealed that 68 % (34 out of 53) of the animals proceeding from the roost behind the timber facade were recaptures from the concrete crevice roost.

Both temperature curves showed clearly in which diverse ways the different materials influence the roost characteristics. The timber cladding presents the same features as the roosts behind sidings mentioned above: strong amplitudes between minimum and maximum temperatures, and no distinct heat storing capacity. The minimum temperatures correspond more or less to the outside temperatures.

A completely different temperature regime is present in the concrete crevice: the daytime temperature is moderate, and in total the minimum and maximum temperatures vary little. The properties of concrete – high heat capacity with a parallel low conducting capacity – lead to a slower heating up, but at the same time also to a slower cooling down. Due to this, a minimum temperature, buffered in relation to the outside temperature, results for the animals. From the middle of May onwards, the roost has minimum temperatures of 13 °C.

With regard to the use of roosts it is indicated that during the relatively cool time, when the animals are underway at night and no young ones are left in the roost, they use the timber cladding roost, due to its warmer temperatures during the day. On days with strong sunlight, when the timber facade heats up to a great extent (> 45 °C), the animals favour the temperatures in the concrete crevice roost, which is 'more pleasant' at this time.

A crevice roost in a wall made of hollow concrete blocks presented temperatures which corresponded to the outside temperatures (figure 69). Due to its easterly exposure it did not heat up very strongly by the sun's radiation. However, it can be supposed that in deeper parts

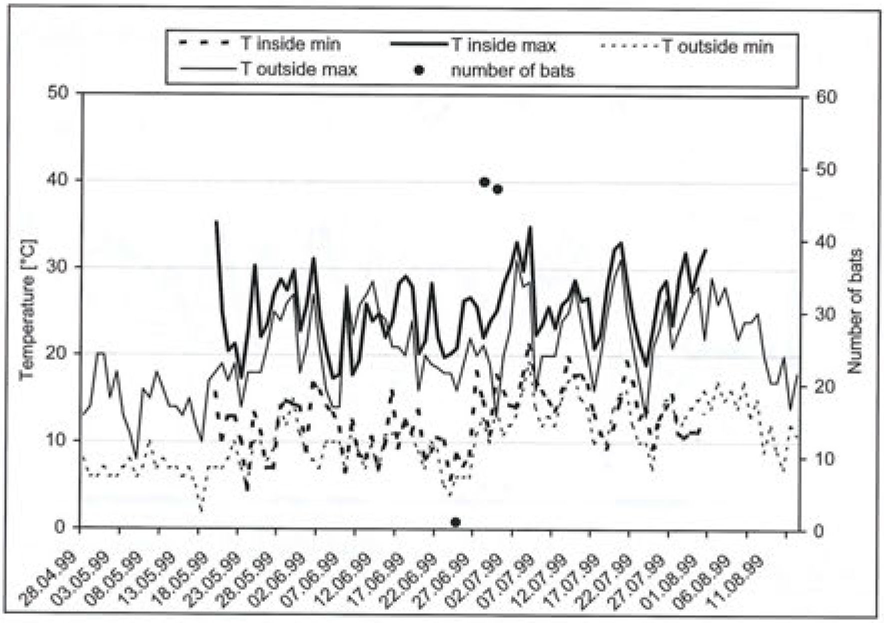

Figure 69: Temperatures in the concrete crevice in Kleinseelheim. Maternity roost of the common pipistrelle. The crevice has an easterly exposure.

of the wall a stronger temperature buffering was given at least during the night. The exclusive use of this roost at the beginning of July, when it was relatively warm, was not surprising.

5.10.2 Intermediate roof

Maternity roost of the common pipistrelle

Strong temperature changes within the course of the day and a relatively low storing capacity of the materials are characteristic for intermediate roof roosts. Accordingly, these roosts, depending on their exposition, can partly present high temperatures. Only small differences were found between the three sample maternity roosts of the common pipistrelle (in the one village) (see figures 70 to 72). The temperature course shown in figure 70 represents a roost which was located in a roof with a NE/SW exposure. Here, temperatures up to 43 °C were reached. In the intermediate roof roost with east-west exposure (figure 71), no such comparably high values are reached. The reason for this might be the exposition, but also the different materials. The nightly temperatures represented in figure 71 show that there must be better heat insulation here, as the temperatures did not decrease as much as in the roost which was hotter during the day (figure 70).

The temperature course for further intermediate roof roosts represented in figure 72 shows that direct sunlight does not influence the temperature, but that the outside temperature alone is significant. However, the minimum temperatures remain clearly over the outside temperature, especially when the young stay in the roost at night.

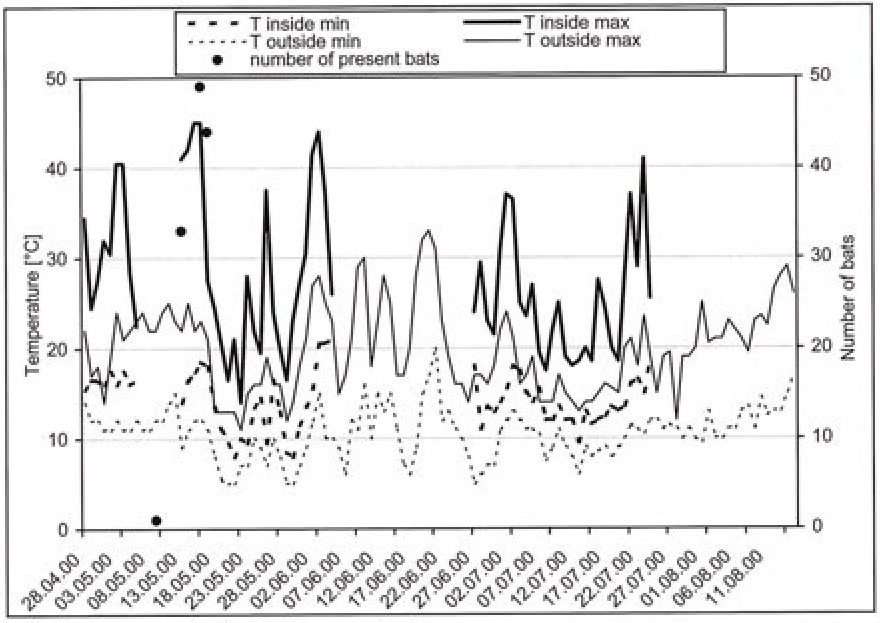

Figure 70: Temperatures in an intermediate roof roost of the common pipistrelle. The roof has NE/SW exposure. The temperature sensor was erected in the opening of a hollow concrete block in the wall (with south-easterly exposure).

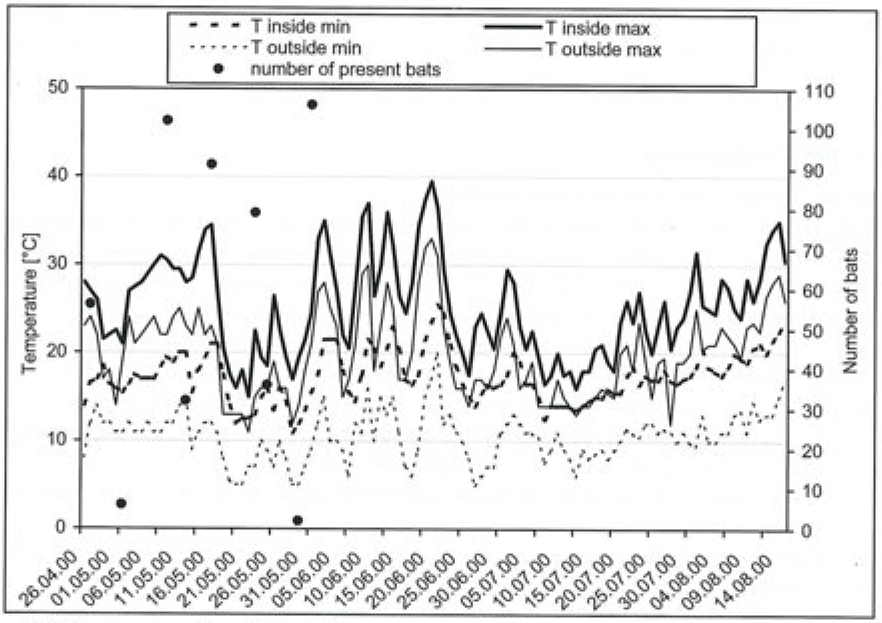

Figure 71: Temperatures in an intermediate roof roost of the common pipistrelle. The roof has E/W exposure.

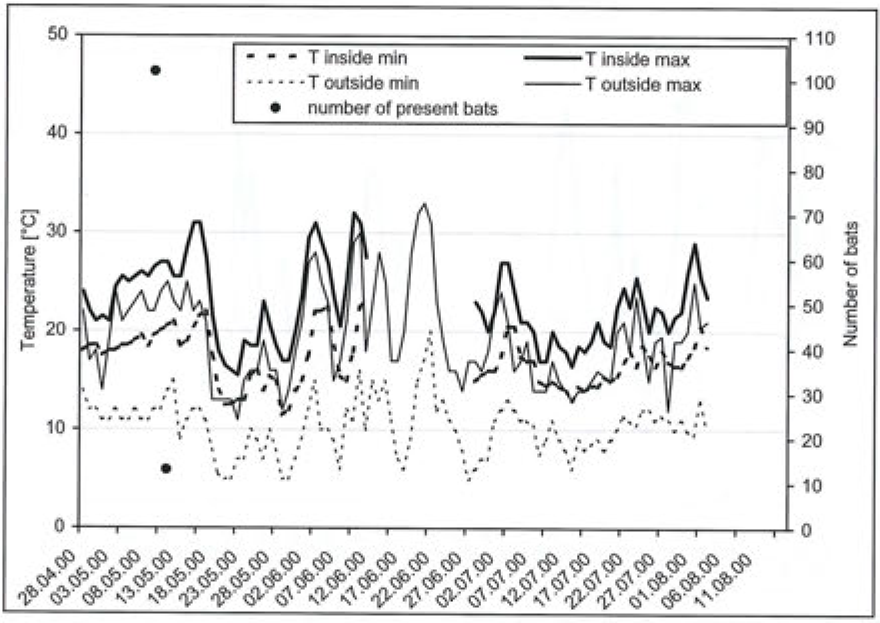

Figure 72: Temperatures in an intermediate roof roost of the common pipistrelle. The roof has NE/SW exposure.

5.10.3 Hollow space in a breezeblock ceiling of a cowshed

Maternity roost of the Natterer's bat

For the first time temperature data could be registered in a maternity roost of the Natterer's bat. The roost is situated in a hollow space in a cowshed's breezeblock ceiling. Remarkable are the very low variations in temperature according to time of day or season (see figure 73). This roost has its own micro-climate, with temperatures between 16 °C and 28 °C, which is due to the permanent keeping of cows in the shed. Due to these constantly high temperatures the bats have excellent roosting conditions. A similar temperature course can be observed in summery warm bat caves in southern Europe. PANDURSKA (1998), for example, reported on natural, summery warm caves in Bulgaria, where there were maternity roosts of the greater mouse-eared bat, and temperatures between 9.2 and 22 °C. CERVERNY & HORÁČEK (1981) found maternity roosts of the Natterer's bat in the Czech Republic, which were situated in a hollow of a chestnut tree and in a hole in the wall of a church attic with temperatures between 19 °C and 35 °C.

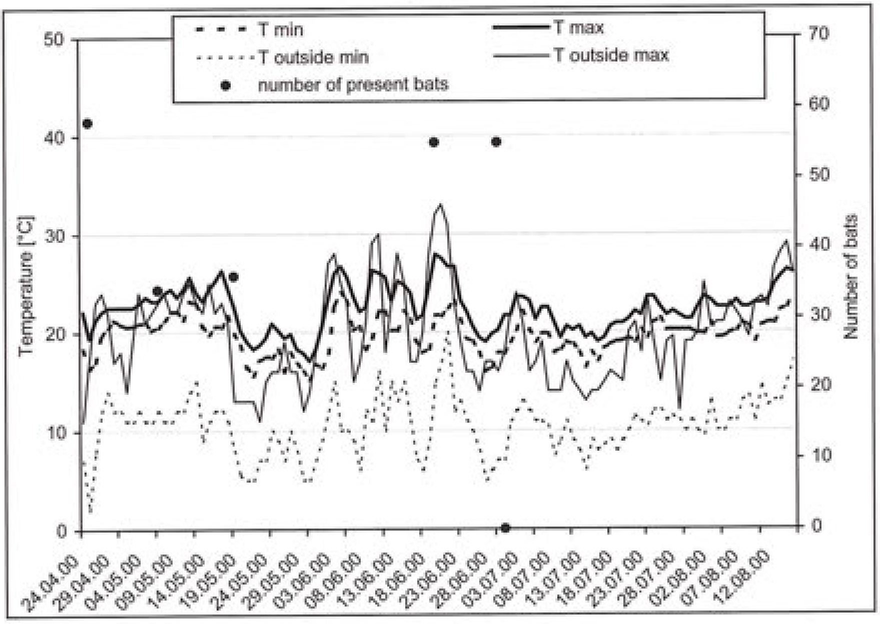

Figure 73: Temperatures in a maternity roost of the Natterer's bat in the ceiling of a cowshed.

5.10.4 Gap between two walls made of hollow concrete blocks

Maternity roost of the serotine bat

This maternity roost which was frequently used in the course of the summer by a serotine bat colony, also using five further roosts a few hundred meters away, was situated between two external walls of a house made of hollow concrete blocks. Here, the animals very probably had the possibility to use hollow spaces in the upper stone row and also the intermediate roof. Thus they were able to switch to warmer areas in case of unfavourable minimum temperatures. The roof had a south-westerly and north-easterly exposure. In the area where measurement was possible, the temperatures lay between 13 °C and 25 °C (see figure 74). The roost was remarkably insulated from the outside temperature. Neither the higher nor the lower outside temperatures were reached in the roost.

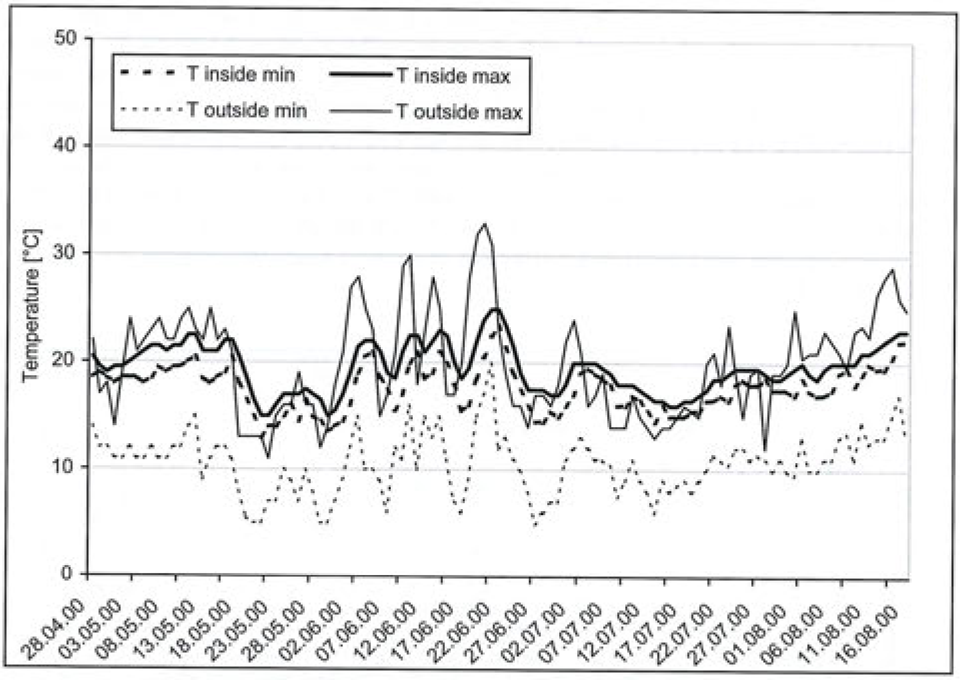

Figure 74: Temperatures in a gap between two hollow concrete block walls frequently used by a serotine bat colony in the year 2000.

Maternity roost of the common pipistrelle

This maternity roost of the common pipistrelle, behind an asbestos cement attica, heats up extremely due to its southerly exposition (see figure 75). Top values of 50 °C in May and often 40 °C or more in the course of July were reached. A low heat storing capacity of this roost type was revealed by the minimum temperatures which basically corresponded with the outside temperatures. Accordingly, it was not surprising that the use of this roost was limited to the early and late maternity period.

5.10.5 Attic

Maternity roost of the greater mouse-eared bat

Maternity roosts of the greater mouse-eared bat are usually situated in attics, where the animals hang freely and can react to their ambient temperature through their choice of hanging place or through their social behaviour. Temperature measurements were carried out at the hanging places of a colony in a big church attic, in order to investigate the correlation between temperature and choice of hanging place. The first two hanging places in the ridge of the roof (F1 and bell) were equipped with three temperature sensors each. One of the sensors recorded the air temperature, and the other two were fixed to the timber on the north-

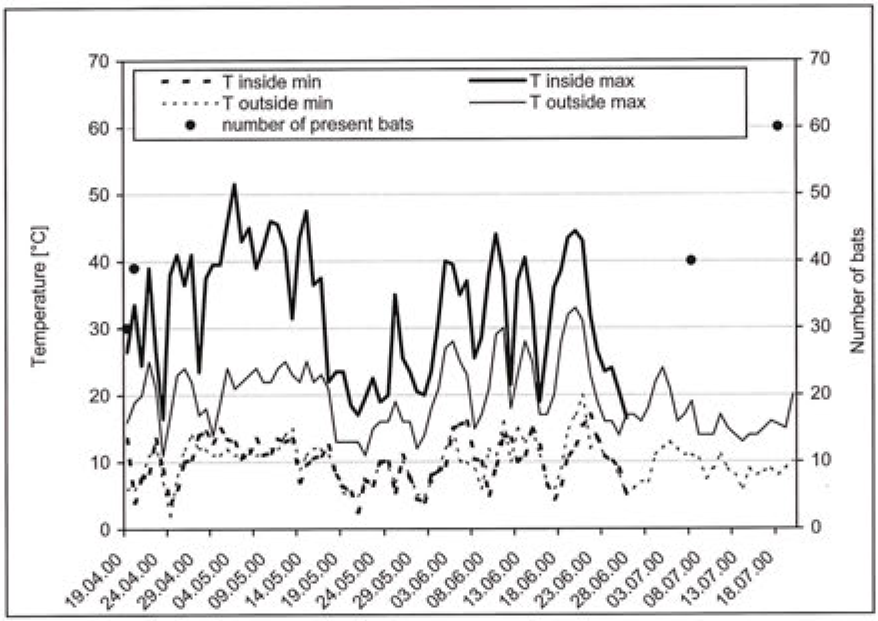

Figure 75: Temperatures behind an asbestos cement attica (an intermediate roof would also be possible), which was used as maternity roost by the common pipistrelle. The exposition was SSW.

ern and southern sides. The two hanging places at the northern and southern sides of the belfry were provided with two sensors each, which also here determined the air and timber temperatures. Furthermore, the temperature was also determined in a hollow space in the wall between nave and aisle, which also temporarily served as a roost. Here, three sensors were installed, namely at the masonry in a non-occupied hollow space and in the air stream of the wall opening. Care was taken with all sensors to exclude the possibility of body warmth raising the temperature.

The temperature measurements and a regular registration of the greater mouse-eared bats' hanging places were carried out in the years 1999 and 2000.

The mouse-eared bats were mostly hanging closely packed in big groups on the uppermost ridge beams. A peculiarity of this church attic is a side aisle which has a wall with a hollow space used by the animals as a hanging place. Furthermore, the animals use the upper area of this side aisle wall (termination edge), which borders on the roof and is somewhat protected. These mass hanging places were not usually changed within one day. However, the hanging places were changed several times within one season. The changes over the year 1999 is represented in figure 76 and subdivided into six phases:

I.	9. 4.–27. 5. 99	All animals were in the wall's hollow space.
II.	28. 5.– 2. 7. 99	The hanging place is the easterly ridge of the roof (F1) above the apse. The bats were usually hanging closely packed at the northern framework planks between the roof rafters. Some animals separated out and returned into the hollow space in the wall.
III.	3. 7.–26. 7. 99	F1-F19 (ridge of the roof): The colony temporarily divided into several big or small groups and frequently changed the hanging places within a short time, by moving farther to the west.

IV. 27. 7.–17. 8. 99 Most animals gathered in field F1 again, while only few of them spent the day in the hollow space in the wall.

V. 18. 8.–28. 8. 99 Only few bats were in the wall's hollow space, single animals on the ridge of the roof; possibly there were day roosts outside the attic.

VI. 29. 8.– 6. 9. 99 About 50 young were at the hanging place at the northern side of the belfry, where they were hanging in the angle of two intersecting beams, while some were still staying in the hollow space in the wall.

In 1999, the greater mouse-eared bats sojourned in the hollow space in the wall from the middle of April until the end of May (see figure 76). The maximum outside temperatures lay almost constantly below 20 °C during that time. Only when the temperatures increased to more than 20 °C did the animals hang in the ridge area. When outside temperatures were low the temperature in the hollow space in the wall was warmer than the ridge area, according to higher heat capacity of the wall. In addition, the animals lost less body heat in the hollow space. From the end of May onwards, the ridge area presented higher temperatures (see figure 77) and the animals sojourned mainly in the ridge area over the summer. Only single animals moved from time to time into the wall's hollow space. In 2000 the outside temperatures were clearly higher in May (between 20 °C and 25 °C) and the animals had already moved from the hollow space in the wall into the ridge area at the beginning of May (see figure 76).

Air and timber temperatures of the roof ridge area (hanging place) were measured in an attic which served as maternity roost to greater mouse-eared bats (see figure 78). While the minimum temperatures were almost equally high, the maximum timber temperatures lay up to 5 °C above those of the air. This reflects the more favourable heat capacity of timber.

According to several statements in the literature, the greater mouse-eared bats leave a roost when it has temperatures of more than 30 °C, or avoid such hanging places (BILO 1990, HEIDINGER et al. 1989, ROER 1988, ZAHN 1998). Hanging places were preferred in the western

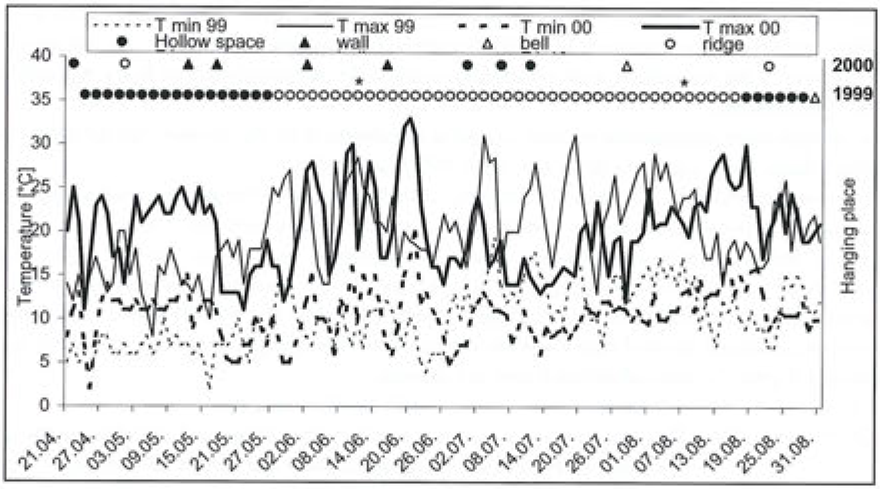

Figure 76: Choice of hanging places in the mouse-eared maternity colony in the church of Gladenbach in the years 1999 and 2000, in relation to the respective outside temperature. * in the course of June and end of July until the middle of August, there were also always bats in the hollow space in the wall; ridge = fields of framework in the ridge area; bel = belfry; wall = hollow space in a wall between side aisle and main room.

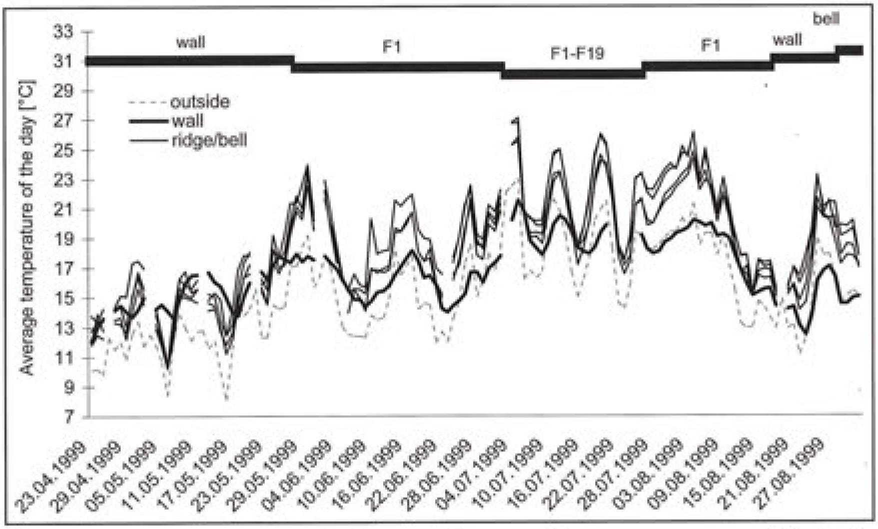

Figure 77: Average daily temperatures in a big maternity roost of the greater mouse-eared bat in Gladenbach in an attic with side aisle and belfry; wall = hollow space in a wall between main room and side aisle.

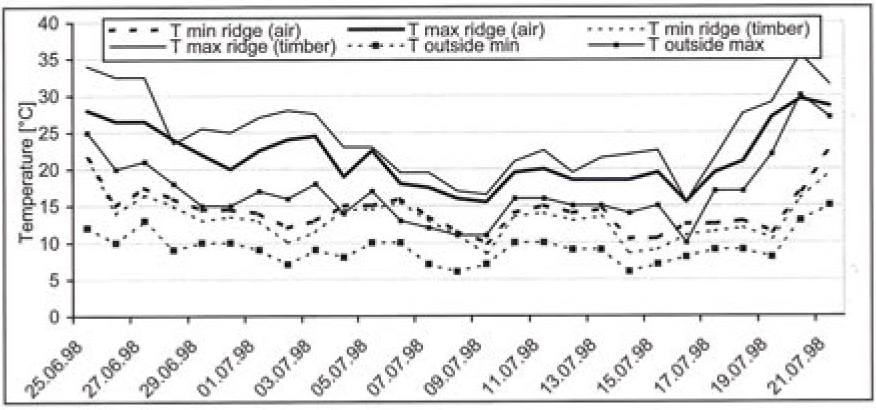

Figure 78: Temperatures in the maternity roost Seelbach. A frequently used hanging place of greater mouse-eared bats was located in the ridge area, which was recorded. The air and timber temperatures (sunny side) of this area were measured.

part of the attic in July when the temperatures can lie between 15 °C and 37 °C (GEBHARD & OTT 1985). HAENSEL (1990) reports on a maternity roost in a shaft of a cellar (temperature 1.5 m above the ground: 13 °C–14.5 °C) with an estimated hanging place temperature of at least 25 °C. ZAHN (1999) determined maximum temperatures of 40.3 °C in a hollow space in a concrete bridge (maternity roost) and minimum temperatures of 11.2 °C with day-night differences of up to more than 20 °C.

5.11 What are the features of a potential roost?

The present results show that the different bat species have certain preferences in regard to their roost. However, *the* optimal, potential roost for a specific bat species does not exist. Instead, as an aid measure it is preferable to provide several slightly different roost types or roosts with somewhat different properties situated in close proximity to each other (compare chapter 7.2 and chapter 10.2). A potential bat roost should have southern or western exposure. The roost opening should be situated at 7–10 m above the ground. The landing area should be rough or it should have edges at the opening, which the bats can hold on to when landing, to then crawl into the roost. It is favourable to place a potential roost in the village's or town's old centre, as there the probability of bats flying by is greatest. The temperatures in the roost should not exceed 35 °C. There are two main possibilities for creating roosts. One possibility is to create a roost with an adequate crevice or hollow space that can be erected outside onto the building, for example a bat board. The other possibility, relevant when building new houses or carrying out renovations, is to integrate appropriate structures into buildings (compare chapter 10.2). In addition, just opening up an attic which is not being used much can constitute a potential roost for attic-roosting bats. In the attic itself, there are in general utilisable structures (planks, peg holes) and further hiding possibilities for bats can be made accessible (see chapter 10.2).

5.12 Summary

Roost types

- The roosts of the **serotine bat** were situated mainly in the attic area of buildings (intermediate roof, flat roof). The roosts of the **whiskered bat** were found almost exclusively behind house sidings (often slate). The **common pipistrelle** is more flexible in its choice of roosts, and can be denominated a pioneer species, as it is quite often found in new potential roosts, for example in the non-plastered hollow conrete block walls of new buildings.
- Although thought to be a "forest species" the **Natterer's bat** actually also belongs to the bat species which roost frequently in buildings. Six of the eleven Natterer's bat roosts within the project area were found in hollow concrete blocks, and two more roosts behind house sidings. The Natterer's bat could be seen regularly foraging in cowsheds and most of the roosts also were situated in or in close proximity to a cowshed.
- The three maternity roosts of the **greater mouse-eared bat** were all located in attics; in one of them the animals also used a hollow space in the wall. A further maternity roost was detected in a roof case.
- The maternity roost mainly used by the **barbastelle bat** was situated behind a damaged, old slate siding of a manor house. A further roost was found behind a metal siding.
- Most of the **common long-eared bat's** roosts were found in attics. The **grey long-eared bat** was found in six crevice roosts (siding and intermediate roof) and four times in attics.

Structural parameters of the roosts

- A large part of the bat roosts have **southern or western exposure**, but there are species-specific differences. The **common pipistrelle** does not reveal many preferences, either concerning roost type or the exposition of their roosts. It uses all directions, with the emphasis on west, south, and east. The **serotine bat** shows a clear preference for southerly and westerly exposed roosts. The strongest preference is by the **whiskered bat** for southerly exposed roosts. This bat species avoids the northerly exposed roosts.

- A large part of the **serotine bat's** roost emergence openings in the low mountain range are, at a **height of 10–12 m,** clearly situated higher than the ones of the **common pipistrelle (5 m–7 m).**
- The **grey long-eared bat, common pipistrelle** and **serotine bat** prefer roosts in the **old centre** of villages, whereas the peripheral areas and the new parts of the village are avoided or populated less frequently.
- According to a rough estimate, it can be supposed that in villages known to have a **common pipistrelle** colony, about 10 % of the locality's buildings have a roost.
- The buildings used by **common pipistrelles** for roosting are over-proportionally **old**, built before 1945 or new buildings. This demonstrates the great adaptability of the common pipistrelle.
- The **material of the landing areas** of most of the **common pipistrelle** roosts was plaster (mostly for intermediate roofs), followed by timber (siding) and slate (siding).

Temperatures in the roost

- **Temperature measurements** in different bat roosts revealed very different kinds of temperature courses, in dependence on the **capacity of heat storage** and of the roost's **location.** Roosts behind sidings do not present a distinct capacity of heat storage and generally present strong amplitudes between minimum and maximum temperatures, which roughly correspond to the outside temperatures. However, the material is also important. Thus, **slate claddings** which have an easterly exposure, heat up to temperatures of up to 35 °C and at night might even present about 20 °C. Common pipistrelles used this type of roost when the maximum temperatures lay between 25 °C and 35 °C. **Timber-cladding** can also heat up strongly, but also has a low heat storing capacity and cools down again quickly. A south-westerly exposed **asbestos cement attic** reached a top temperature of 50 °C in May. During this time, no animals were present. **Stone crevice roosts**, on the contrary, are characterized by a high capacity of heat storage (slow heating up, and also slower cooling down of the roost) and as a consequence there were more moderate amplitudes in temperature during the day. Temperature measurement of **red sandstone blocks** (serotine bat roosts) revealed temperatures of about 15 °C at night, due to heat storage. This is especially significant for the young which are left behind in the roost at night.
- In a westerly exposed **roof case** (panelling under ease) used by **serotine bats** (with **asbestos cement cladding**) maximum temperatures of up to 42 °C could be measured, during the animals' presences.
- The **common pipistrelle** switched between two roost types (timber-cladding and concrete crevice). While the **timber-cladding** can heat up to more than 40 °C, the temperatures in the **concrete crevice** reach a maximum of 31 °C. Especially in May, during pregnancy, the common pipistrelles use the "warm" roost. The minimum temperature in the concrete crevice, which was also chosen as roost after the birth of the young, constantly exceeded the minimum temperature behind the timber-cladding by 5 °C.
- Roosts in the **intermediate roof** could heat up to temperatures of up to 43 °C. The roosts cool down at night to different extents, depending on their exposition and also of the roof's insulation.
- An unusual, but quite typical roost of the **Natterer's bat** is the **hollow space in the breeze-block ceiling** of a cowshed. The roost has its own micro-climate with stable temperatures between 16 °C and 28 °C, due to the permanent presence of cattle in the shed.
- The **greater mouse-eared bat**, which roosts in **attics**, changes its hanging places according to the temperature of the roost. The animals hang up in the ridge area, only when the

temperature has risen to more than 20 °C. With lower outside temperatures, the hollow space in the wall is warmer than the ridge area, as the former has a greater heat capacity, and the latter cools down very quickly.

Potential bat roost

- A potential bat roost should have southern or western exposure, and the roost opening (with a rough landing surface) should be situated in 7–10 m above the ground.
- It is favourable to place a potential roost in the old centre of a village and to create several roosts in the immediate vicinity (to allow roost switching).
- The temperatures in the roost should not exceed 35 °C.
- In order to create a roost, additional structures, such as a bat board, can be fixed to the building, or else appropriate structures can be integrated into new buildings or included in renovations.
- The opening up of attics increases the number of potential roosts.

6 How do bats explore their roosts?

6.1 Introduction

The spatial orientation of bats has been poorly investigated, compared to that of birds, for example. Knowledge concerning such questions generally requires a great expense in time and money, due to the bat's hidden way of living, its echo-location and its nocturnal activity. In contrast to birds, which orientate visually to a great extent, the physical properties of ultrasound for echolocation make bats quite "short-sighted". This is especially important for the use of space during the summer, in other words for the seasonal use of hunting grounds and roosts. During their period of reproduction, female bats use vast areas that are much bigger than the territories of song-birds during breeding time. From this rises the question of how bats are able to explore such vast areas and to move securely within them. For the overcoming of the sometimes great distances between summer roost and hibernaculum, other senses apart from hearing and sight, seem to be significant (e. g. magnetic orientation, NEUWEILER 1993). Concerning a new creation of potential bat roosts, the question rises whether house-dwelling bats might use a certain searching pattern to find adequate roosts. As the females amongst the native bat species gather in summer colonies, it is furthermore probable that these animals inform each other about the location of roosts. Only such a communication would make it possible, for example, for serotine bats to use night roosts in groups and then leave them one by one in the early morning to gather again in a day roost in a different location (chapter 6.6.3).

The physiological details of the senses, which concern social communication of bats, can only be investigated in laboratory experiments. Within the framework of the present studies, there were only ecological field investigations, which were not allowed to influence the bats' natural behaviour. Nevertheless, we could investigate some aspects of the transmission of information among bats. Our research concerning such questions was realized basically with the common pipistrelle, swarming at the hibernaculum, at invasions and at maternity roosts. The common pipistrelle was chosen for the following reasons: it is very abundant within the project area, so that a sufficient database could be guaranteed; there are maternity roost assemblages in almost all villages; mass hibernacula of the common pipistrelle are known, where thousands of common pipistrelles have continously been observed or captured; and invasions of common pipistrelles take place regularly in the very town centre of Marburg. The common pipistrelle can therefore be adequately systematically recorded.

6.2 Swarming of the common pipistrelle at the hibernaculum

Investigations of hibernacula played a subordinate role in the framework of the T+D project. An exception were the mass hibernacula of the common pipistrelle. Taking this species as an example, the bats' behaviour at the hibernaculum was planned to be observed during the whole year. Summer investigations at hibernacula played a subordinate role for many years in central European research on bats. Only in the last decades the investigations have been intensified (e. g. GRIMMBERGER & BORK 1978a, GRIMMBERGER & BORK 1978b, DEGN 1987, KALLASCH 1994, KIEFER et al. 1994, KUGELSCHAFTER et al. 1995, SIMON & KUGELSCHAFTER 1999). The most recent studies have been encouraged amongst others by the fast development of technical equipment, like video with infra-red lighting and other electronical surveillance techniques (compare KUGELSCHAFTER et al. 1995). But also common methods like trapping and individual banding played an important role in the research (KALLASCH 1994, SENDOR & SIMON 2000).

Due to several reasons, in most of the studies the use of methods was or had to be limited to those which did not allow an wholistic investigation into all aspects of bats, neither spatio-functional, nor in phenology, or populationecology (e. g. GRIMMBERGER 1979, KALLASCH 1994, KIEFER et al. 1994, KUGELSCHAFTER & HARRJE 1996). Considering these experiences, we tried to get a maximum of data and information about bats' summer activity, taking a mass hibernaculum of the common pipistrelle as an example, and employing all possible methods. This meant in detail:

- Trapping over the whole year and individual banding of common pipistrelles in mass hibernacula (approximately 18,182 captures and 13,744 bandings);
- Automatic registration of entries and emergences of all bats over the whole year (light barrier);
- Automatic recording of activities (ultrasound registration) over the whole year;
- Automatic recording of climatic conditions (e. g. temperature, atmospheric humidity);
- Capturing and banding common pipistrelles at as many invasion sites as possible (about 1,291 captures and 1,219 bandings);
- Capturing and banding common pipistrelles at as many summer roosts as possible in the area around the hibernaculum (about 5,341 captures and 3,950 bandings);
- Targeted recaptures over several years at the villages where trapping had already occurred (5,927 recaptures); and
- Experimental investigation into the behaviour of roost exploration.

6.2.1 Investigated hibernacula

At the beginning of the investigations, a mass hibernaculum of the common pipistrelle was already known in the project area. This hibernaculum was in a vault under the knights' hall in the 700 year old Marburg Castle. The common pipistrelles hibernate there in deep wall crevices (see figure 79). The hibernaculum was discovered in the mid-1980's and has been investigated more intensively since 1995 (SIMON & KUGELSCHAFTER 1996). Furthermore only few hibernaculars of single pipistrelle bats are known.

In winter 1996/97 we were informed about numerous bats discoverd during roof renovations at a factory in Korbach (in northern Hesse). This turned out to be a further mass hibernaculum of the common pipistrelle in the region (distance: Marburg – Korbach: about 53 km bee-line). In contrast to the hibernaculum in the historic vault of the Marburg castle, this hibernaculum was situated in the concrete circular attica of a factory about 20 years old. Therefore, the hibernaculum, which was located at about 20 m height, was surprisingly young and resembled very little the places commonly characterized as typical hibernacula of bats.

6.2.2 Seasonal phenology

Taking the entering and emerging activities at the mass hibernaculum of Marburg Castle as an example, the use of hibernacula by common pipistrelles was recorded for the whole year of 1997 (see figure 81 and figure 82). Here, light barriers can be used to count the number of animals in the hibernaculum by balancing the emergences with entries. This is especially valid for the period in the year when bats leave their hibernaculum in winter, from about February to March. During this period, several hundred animals were proven to leave the roost during a single night (compare figure 80). But also mass entries of several hundred common pipistrelles during single nights could be counted by means of light barrier balances during the months November and December when bats move into their hibernaculum (figure 81).

Figure 79:
Common pipistrelles, hibernating in a crevice in the mass hibernaculum of the Marburg Castle.

The relationship between the wintery outside temperature and the entries and emergences is clearly visible in the diagrams.

In the summer months, the daily light barrier balances are largely levelled out, so that it can be recognised that the bats, despite entering the hibernaculum at night, do not stay there during the day (see figure 82). The greatest amount of entries and emergences was measured especially in August during the warmest time of summer: up to more than 1,500 entries and emergences (compare figure 82). The least activity in the hibernaculum was registered for the months April and October.

The insights and results concerning the use of roosts at the mass hibernaculum in Marburg, were planned to be checked by comparative investigations at the hibernaculum in Korbach. Due to difficult access to the roost, as it was situated more 20 m above ground-level, the entrance and emergence gaps couldn't be equipped quantitatively, but only representatively in a section of the roost, with surveillance equipment.

The times and time periods of activity were almost identical. This was shown for example when comparing the summer swarming during the months August to September (compare figures 85 and 86). While the balances of the entries and emergences in the Marburg Castle's

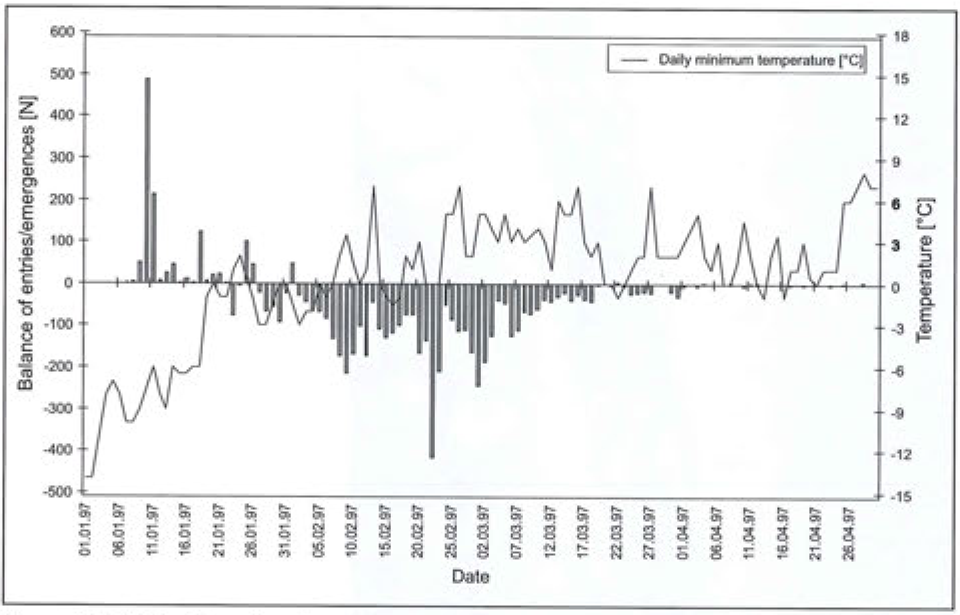

Figure 80: Light barrier registrations during the late winter in mass hibernacula of the common pipistrelle, in the vault in Marburg castle. While in January there are still bats entering the roost, the first common pipistrelles already leave the mass hibernaculum in February.

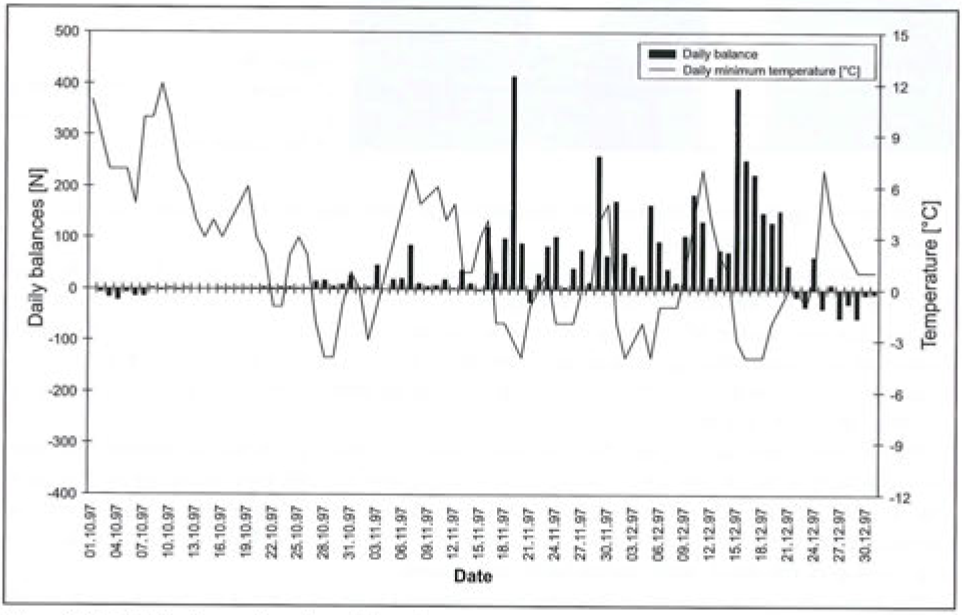

Figure 81: Light barrier registrations during the early winter in a mass hibernaculum of the common pipistrelle in the basement of the Marburg castle (daily balances = entries minus emergences).

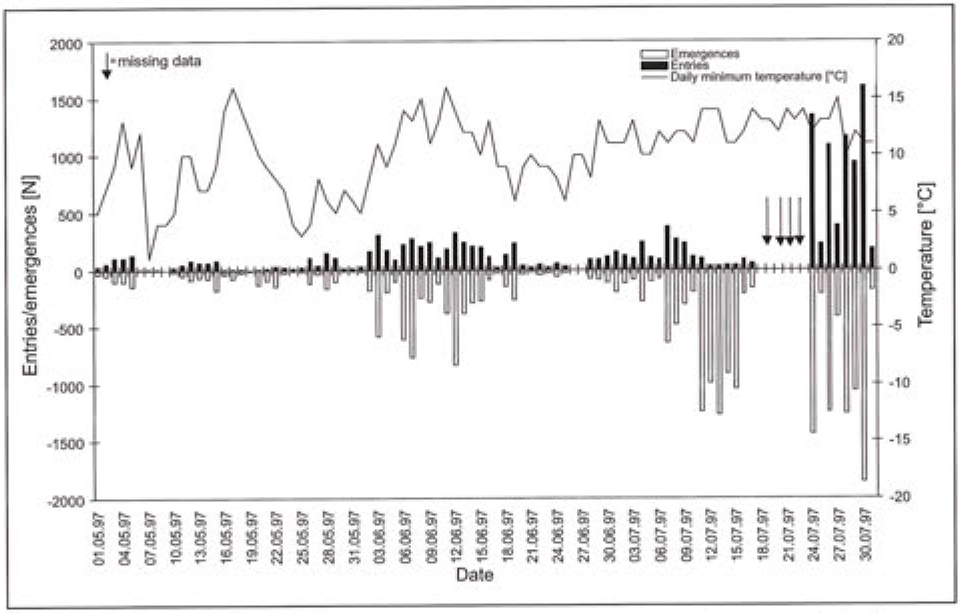

Figure 82: Light barrier registrations during the spring/summer in the mass hibernaculum in the basement of the Marburg castle.

vault were almost levelled out, in Korbach conspicuous differences were recorded (more emergences than entries). This difference, however, can be attributed to the incomplete surveillance.

By accumulating light barrier balances during the winter months, it was possible to count winter stocks in a sufficiently accurate way. Thus, up to 5,000 hibernating common pipistrelles could be registered in the Marburg hibernaculum in the last years (compare figure 83), while in Korbach at least 1,500 animals were detected in a partial area of the roost (see figure 84). The number of common pipistrelles taking part in summer swarming at the Marburg Castle is about 20,000 to 30,000 (SENDOR & SIMON 2000). This was calculated by banding and recapturing. In Korbach, no banding project was carried out, so that it remains unknown how many common pipistrelles really take part in the swarming.

The seasonal use of the mass hibernaculum in the Marburg castle has been recorded for seven years, and has not changed either remarkably or in any trend during this period of time. The annual fluctuations in the swarming activity or roost use in winter are determined mainly by the weather. The direct comparison with the mass hibernaculum in the factory hall in Korbach did not lead to other observations, so that the trends presented here, can be viewed as typical and generally valid for large hibernacula of common pipistrelles.

Apart from the general manner of observing the seasonal incidents in the mass hibernaculum, it was of special interest to see which animals take part in the swarming. This could only be assured by captures and bandings in the hibernaculum. A comprehensive program of trapping made it possible to accurately register the order of swarming in terms of the age and sex of the common pipistrelles:

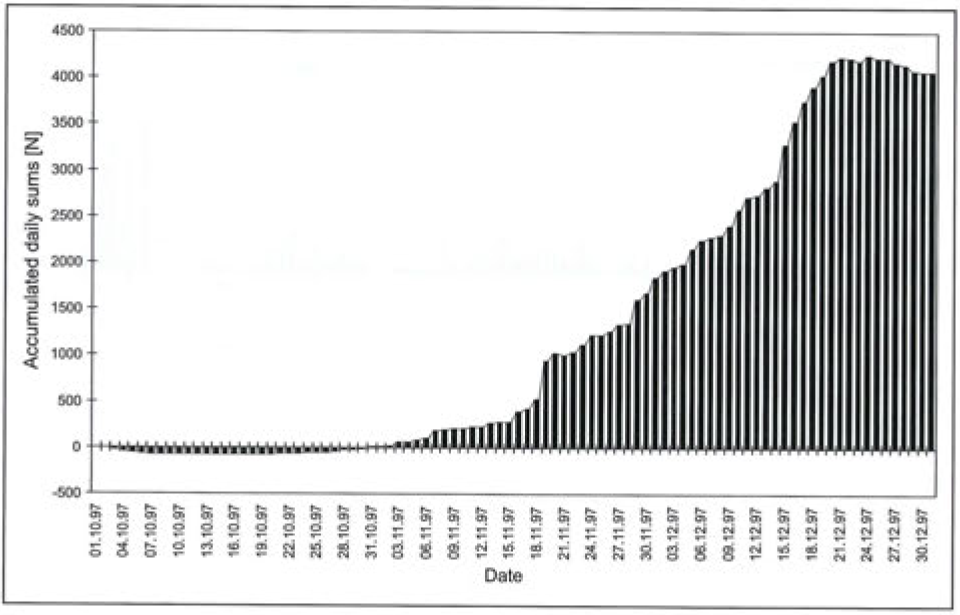

Figure 83: Entries of common pipistrelle into the mass hibernaculum in the vault of Marburg castle. The stock number resulted from cumulated daily balances of light barrier recordings.

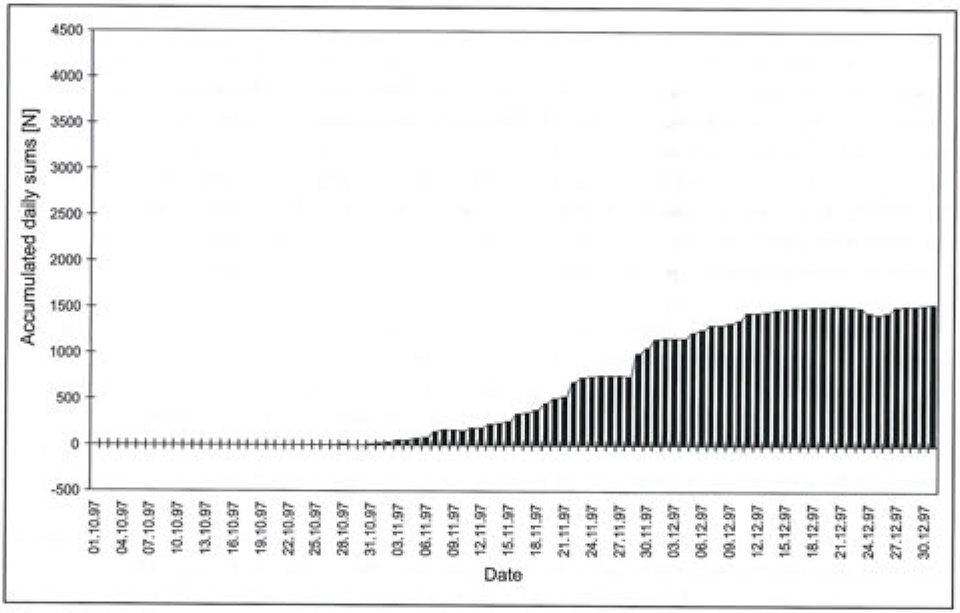

Figure 84: Entries of common pipistrelles into the hibernaculum in the factory in Korbach. The stock number resulted from cumulated daily balances of light barrier recordings.

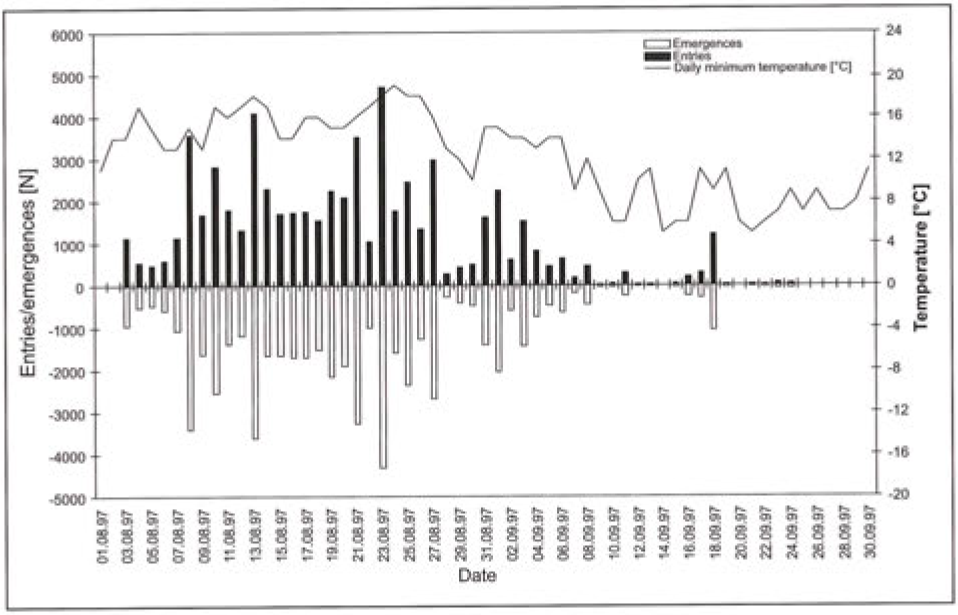

Figure 85: Light barrier registrations in summer in the mass hibernaculum in the vault of Marburg castle.

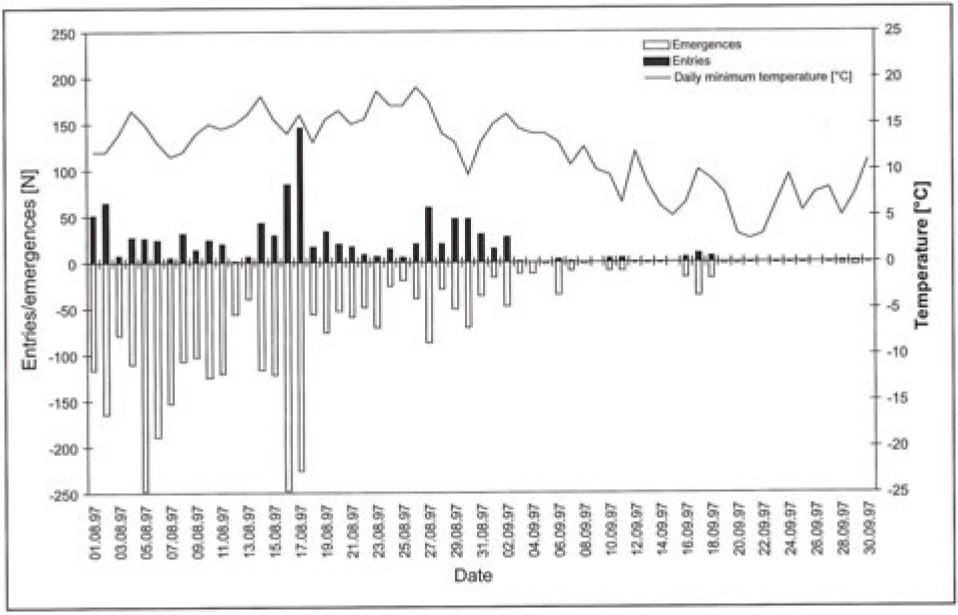

Figure 86: Light barrier registrations in summer in the common pipistrelle's mass hibernaculum in the factory in Korbach.

- In spring or early summer, from the middle/end of April to the beginning/middle of July, almost exclusively adult males swarm at the hibernaculum. Sometimes some adult females who are not reproducing that year take part.
- In July, more and more adult females inspect the hibernaculum. These females are those which had been involved in reproduction.
- By the end of July, often the first young of the year appear at the hibernaculum. At this time, most of the old males have left. The swarming is dominated by old females.
- In mid-August at the latest, the number of young continues to increase and old common pipistrelles are rarely captured.
- By the end of August, practically only young bats are seen swarming.

The captures over the year 1997 in the hibernaculum of Marburg Castle constitute a prime example for this seasonal order in terms of age and sex (see figure 87).

The order described above, of adult males first, followed by adult females and the young bats last, is not a casual phenomenon, but takes place repeatedly every year. Nevertheless, there is not any special order to observe during the immigration phase into the hibernaculum in winter. A plausible and comprehensible explanation for the described phenomenon seems to be the following one: the males have much more "free" time during early summer and summer, compared to the females. The reason for this is that the females become pregnant in spring and therefore need to increase weight as soon as possible, so that they can give birth at the right time. This means that females not only need enough food, but also should not fall into a torpor, as otherwise the body temperature would not be constant enough to assure a sufficient development of the foetus. The males, in comparison, having generally a lower body weight, need less energy and can spend more time in torpor in cold weather situations. Radio-tracking studies within the framework of our investigations showed that male common

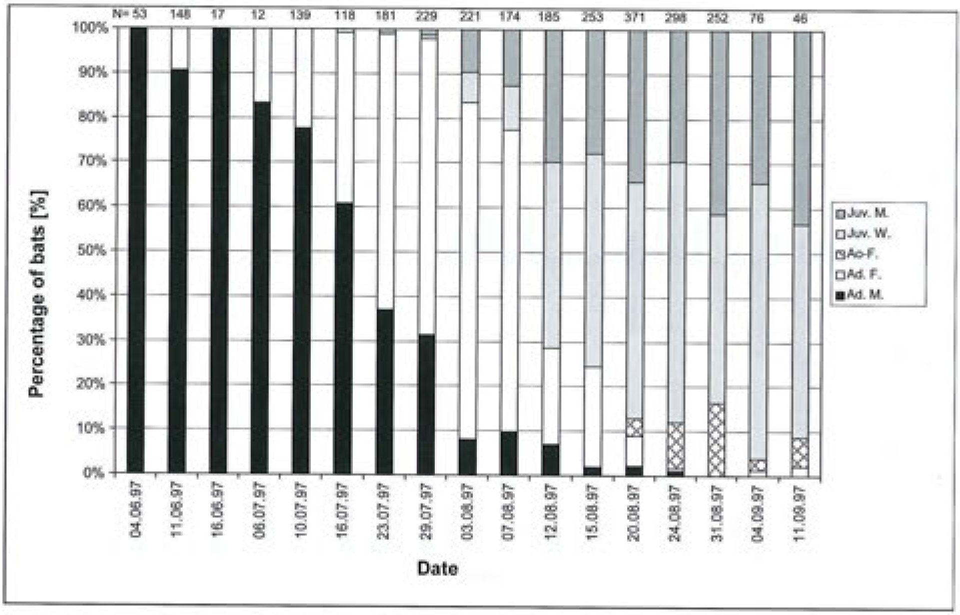

Figure 87: All captures of common pipistrelles during the summer of 1997 in the mass hibernaculum of the Marburg Castle. The captures are distinguished here according to sex and age.

pipistrelles cover shorter distances on their hunting flights than females. The different, sex-specific energy need is especially drastic during the lactation phase. Then, the females still have to suckle up to two young. It is surely due to energy-conserving reasons that the females gather together in the maternity roosts, as by moving up tightly together, heat loss can be reduced , especially for the young. Males and non-reproductive females, on the contrary, live mostly individually, without the possibilities and need for social thermoregulation. Males (and non-reproductive females, Ao) can therefore reconnoitre known hibernacula or also track down new hibernation possibilities, without risking their energy reserves. The males could therefore assume the role of messengers. The regular and remarkable swarming of the males at hibernacula could entice the females to these places. After rearing the young, at the beginning to middle of July, the females have to recover quite fast to accumulate enough energy reserves for the coming winter. Added to this, the mating period begins in August, and from the end of September onwards, colder night temperatures lead to less hunting success. For this reason, it is an advantage for the females to be "shown" hibernacula by the males' swarming behaviour. At the same time, the females, for their part, have to show the hibernacula to their offspring, as the young probably do not follow the males' calls. Only this way can it be explained that at one roost of the common pipistrelle, several thousand animals of a region covering at least 2,000 km^2 arrive at the same hibernaculum within only a few days.

6.2.3 Swarming behaviour at and in the hibernaculum

The exact swarming behaviour of common pipistrelles at and in the hibernaculum is difficult to observe, as the amount of animals make it impossible to identify and follow an individual over a long period. Especially in warm summer nights, several hundred individuals swarm at the same time within a limited area. For the human observer, this "air traffic" looks disordered to chaotic. Despite the high flying density, there are no mid-air collisions: the animals seem to dart to and fro. The spectacle starts from May/June at the latest, mostly after sunset, but only by midnight in great numbers. It seems that the bats need a certain length of time to get to the hibernaculum. It is also possible that hunting still takes place right up to the sighting of the hibernaculum. Though the nightly activities in the hibernaculum can partly be observed excellently with a video camera and infrared lighting, the individual behaviour remains unrevealed. For this reason, single individuals were captured, and banded with miniature chemiluminescent light sticks (see chapter 3.1.7), and could thus be observed very well at night with the naked eye, due to the fluorescent shining lights. This way the individual swarming behaviour could be studied, distinguishing between adult males, adult females and young. This led to the insight that young bats and reproducing females inspect the hibernaculum for a clearly longer time than adult males. The average time of stay was 6.3 minutes for the adults (95 % confidence interval 3.2–9.3 min), and of 10.8 minutes for the young (7.7–13.8 min). Reproducing females swarmed 10.4 minutes on average (7.9–12.9 min) (SENDOR & SIMON 2002). By doing so, the animals disappear for some minutes into the gaps and crevices of the hibernaculum. The exploration of the hibernaculum therefore means only a quite short time of stay in the actual roost, including the exploration of specific hiding possibilities. The time of stay in the nearest surroundings of the hibernaculum can not be detected with the described method. Nonetheless, the radio-tracking of ten individuals at the hibernaculum of Marburg revealed that the animals leave the area around the hibernaculum quite quickly (within 1–5 minutes) (see following chapter).

When swarming at the hibernaculum, each individual is therefore involved only a short time, and a real "coming and going" takes place. Simple counts or recordings of activities of any kind (e. g. via video/audio) during the swarming cannot provide a reliable indication of the number of bats involved.

6.3 Spatiofunctional correlation between hibernaculum and summer roost (radio-tracking)

Numerous spatial connections between colony villages and the hibernaculum in the Marburg Castle's vault could be proved by means of individually banded common pipistrelles and by targeted recaptures (among 33 villages over 379 banded individuals, compare chapter 7.5.1). The common pipistrelles come from a surrounding area in a radius of up to approximately 40 km. Until now few facts are known about the exact behaviour of bats in the late summer. Within the annual life cycle of common pipistrelles, this is the phase when maternity roost communities dissolve relatively quickly, and the animals retire, individually or in small groups, to mostly unknown roosts. At this time, the search for roosts of the common pipistrelle is almost always unsuccessful in areas of human settlement – the animals seem to have disappeared. At the same time – from the middle of July until the end of August – more and more common pipistrelles are observed during the night at the hibernaculum. This mismatch – between the numbers of (apparently) disappearing bats in villages and the increase of common pipistrelles at the hibernacula – can lead to the supposition that in the vicinity of the hibernaculum there is not only a change in the amount of activity but also that the animals settle there temporarily (in so-called intermediate roosts). Furthermore, it is also probable that especially the males might search their mating roosts close to the hibernacula, so that real "courtship centres" are formed.

It was planned that the following questions which have to do with the spatial correlation between summer roosts and hibernacula, or with the swarming at the hibernaculum during the summer months, would be further examined:

- Do the common pipistrelles, swarming at the hibernaculum in late summer, use "intermediate roosts" in their immediate surroundings?
- Do the swarming common pipistrelles spend the whole night at or in the hibernaculum?
- Do the common pipistrelles search for hunting grounds in near proximity to the hibernaculum?
- Do the animals visit other hibernacula during their exploration phase?
- Do the common pipistrelles use certain structures or guiding elements (e. g. riverside vegetation, edge of the forest, etc.) to reach places which are further away?

To clarify these questions, ten common pipistrelles (1 juvenile female, 7 adult females, 2 adult males) were captured in the Marburg Castle and miniature transmitters glued to their backs between the end of July and beginning of August of the years 1998 and 1999. The animals were set free at the only entry and emergence gap of the hibernaculum, about 1 hour after the capture, mostly between 0:30 a.m. and 1:30 a.m. For this aim, only those common pipistrelles were selected, which had already been banded with arm clips, and of whom the village of the summer roosts were known. Therefore, a potential aim of the respective animal was known. Common pipistrelles of unknown origin were not considered, as here a pursuit of these animals would have been less successful. In order to select the right animals, during a trapping session in the hibernaculum the band number of each recaptured bat was immediately checked, until an appropriate bat was found. For the search and pursuit of the animals, four teams of two people were formed, each team having a car. All teams were equipped with receivers and 2-way radios. The animal was set free by a team after the three other teams had brought themselves into favourable positions (e. g. hills, lookout towers) where radio transmission and the bearing of the animal were possible.

Results of the "long distance" radio-tracking

The flying time and flying route could be sufficiently determined for seven out of ten radio-tracked common pipistrelles (see table 23). With the exception of one common pipistrelle, all animals flew immediately in the same night from the hibernaculum back to the already known summer areas (radius of up to 5 km around the village of the `original´ maternity roost). Distances of up to 22 km were covered this way. None of the animals was found again in a known summer roost, but all in "new" roosts, which were used individually by them. Six common pipistrelles used roosts in villages near the maternity roost colonies. Only four individuals flew directly back to the villages where their maternity roosts were known (by us!) to be located. The animals flew with average velocities of up to 18.5 km/h from the hibernaculum to the summer area. To calculate the velocity, the theoretically shortest distance (bee-line) was assumed. Average flying velocities of 20.5 bis 22.7 km/h for straight flights of common pipistrelles have been determined by KALKO (1991), using photographic techniques, on distances of 5 m. The deviation of the determined velocities within a scale of about 10 %, are quite low, and can be explained by the actual route taken: it can be assumed that the common pipistrelles did not cover the long distances exactly in a bee-line, but used smaller detours, for example around mountain tops or especially wide open areas. These detours from the "ideal line" are low at 10 % and indicate indirectly that common pipistrelles do not have to orientate themselves on a small scale to linear structures for the long-distance flight. The covered distances along clear-cut connecting lines would be at least about 20–40 % longer (own measurements on the basis of topographic maps), and the flight would be correspondingly longer. The relatively high velocities of the common pipistrelles during the long-distance flight brought about some difficulties for direct pursuit during radio-tracking. In difficult terrain, especially in wooded areas, it was almost impossible to follow the animals. During their flight, the bats with transmitters could rarely be observed with the naked eye, but the pursuit by telemetry was almost a complete success. The common pipistrelles must have flown above the treetops, as only thus the high velocity can be explained. The following evaluations are of further interest (compare table 23):

- Five out of the ten radio-banded animals when first captured were adult. Four were juvenile and were only recaptured as adults in the following years. Among the original adult animals only one changed its village (move to another village), four animals flew back to the village where they had first been captured.
- For common pipistrelles which had been captured as juveniles at the first village of capture, there was a completely different picture: all four animals moved to another village; the average distance from the village of first capture was 3,525 m.
- Apart from eight females, two males were also equipped with transmitters. The males, both slightly older than one year, returned to villages near by their natal village after swarming.
- The only young (female) to be equipped with a transmitter returned to the colony's village. This animal was located for the second time already swarming at the hibernaculum, although it was for sure only about three months old (compare table 23).
- One of the females used a hunters' lookout tower at a forest clearing over several days as day roost, while all the other animals were found at building roosts.

Altogether, it was shown that common pipistrelles are extremely mobile, and presumably fly from the summer areas to the hibernaculum and back within a single night. During the nights, they only visit the hibernaculum for a short time, and do not spend the day in the hibernaculum, nor in the near surroundings. Near the hibernacula, there are apparently no collections of "intermediate" roosts or mating roosts, which are visited or reconnoitred in the same night. The telemetry study indicates that the bats are underway purposefully, and

Table 23: Overview of the common pipistrelles that were fitted with transmitters at the hibernaculum (Marburg Castle) and could be followed by telemetry to the given destinations.

No. of ring	Sex	juv./ ad	Mass [g]	Date	Bat fitted with transmitter	Locality of capture and destination (distance loc. of capt. destination [m])	Distance from castle	Flying time castle destination
13738	f	juv.	4.8	28.07.98		Wommelshausen		
		juv.	5.2	20.08.98		castle		
		juv.	4.9	01.09.98	x	castle		
				01.09.98		Wommelshausen (0)	20 km	1.1 h
116120	f	ad.	6.3	29.05.97		Lohra		
			6.0	28.07.96		castle		
			6.2	29.07.97		castle		
			6.5	18.08.98	x	castle		
				18.08.98		Kehna (2.600)	10 km	??
120879	f	ad.	5.4	02.09.96		castle		
			5.3	26.05.98		Lischeid		
			5.8	11.08.98	x	castle		
				11.08.98		Lischeid (foraging)	21 km	< 1.5 h
				14.08.98		Lischeid (roost) (0)		
121438	f	juv.	5.2	15.08.97		castle		
		ad.	4.7	29.0498		Kleinseelheim		
			5.4	16.07.98		Kleinseelheim		
			6.1	09.08.98	x	castle		
				09.08.98		??		
				10.08.98		Kleinseelheim (0)	8 km	??
124206	m	juv.	4.6	13.07.97		Mornshausen		
	m	ad.	5.3	19.07.98	x	castle		
				19.07.98		Allendorf (3.100)	14 km	ca. 1 h
124333	f	juv.	4,2	16.07.97		Obereisenhausen		
	f	ad.	5,4	26.07.98	x	castle		
				26.07.98		Hommertshausen (2,250)	18,5 km	ca. 1 h
124564	f	juv.	4.2	24.07.97		Elmshausen		
	f	ad.	6.2	19.07.98	x	castle		
				19.07.98		Diedenshausen (4,500)	11 km	< 1h
123559	f	ad.	4.4	13.05.98		Dreihausen		
	f	ad.	6.2	20.07.99	x	castle		
						Dreihausen (0)	10.5 km	0.75 h
13566	m	juv.	3,9	22.07.98		Albshausen		
	m	ad.	5.3	25.07.99	x	castle		
						Schwarzenborn (4,250)	11.5 km	0.75 h
12236	f	ad.	5.0	18.05.99		Gönnern		
	f	ad.	5.5	04.08.99	x	castle		
				05.08.99		Gönnern (0)	22 km	?

do not rove about in the area. All ten animals equipped with a transmitter flew back to their summer areas in a targeted way (compare figure 88). These areas are also kept in late summer, after the maternity period. Presumably, the common pipistrelles are very loyal to their village, although they regularly visit hibernacula at distances of more than 30 km. Nonetheless, the "migrations" into the hibernacula take place within only a few hours of a single night. The hibernacula are presumably situated exclusively in the nocturnal homerange of the common pipistrelles. It is not necessary for them to spend the day in "intermediate roosts" to explore or reach a hibernaculum, and this would only occur as an exception. The big hibernacula are not found casually, but are shown especially to the young (see above).

Only in spring, roost switchings beyond the local radius seem to occur occasionally, as during this time bats are discovered regularly at greater distances from the actual summer roosts (compare chapter 7.4.1).

Furthermore, the exploration of the hibernaculum seems to occur in groups. Thus, in the year 1996, up to three common pipistrelles of one maternity roost colony from Lohra (12.6 km from Marburg) could be captured each several times in one night (see figure 89). In the summer of 1997, these bats could then by means of their arm-clips be identified together in one maternity roost. During the same summer, five bats of the same colony explored the mass hibernaculum in one night.

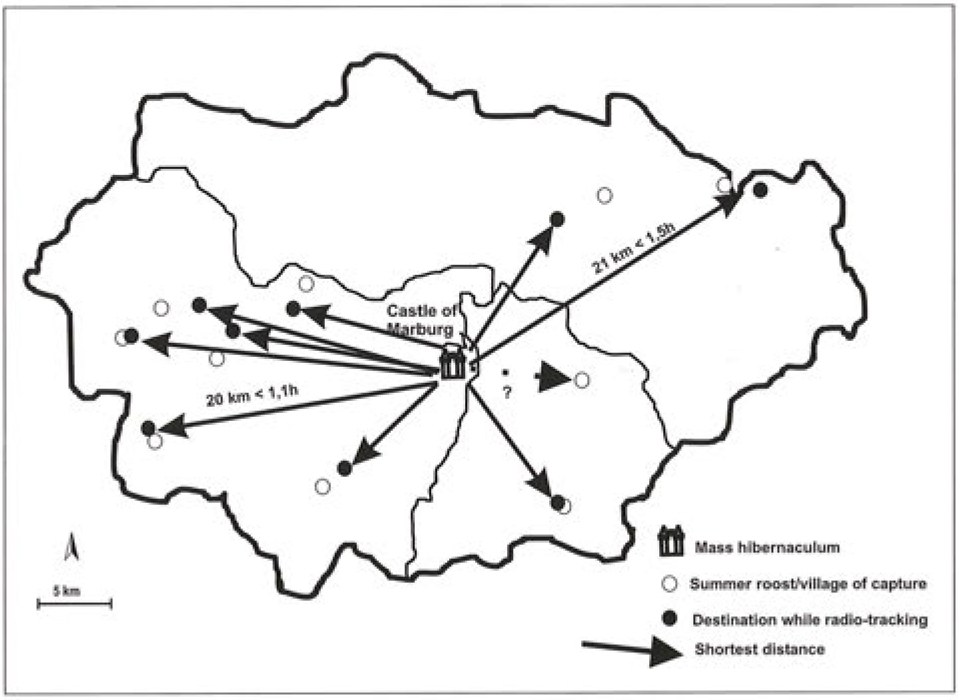

Figure 88: Minimal distances covered by common pipistrelles fitted with transmitters during the summer swarming at the hibernaculum. The distances and flying times are given for two individuals.

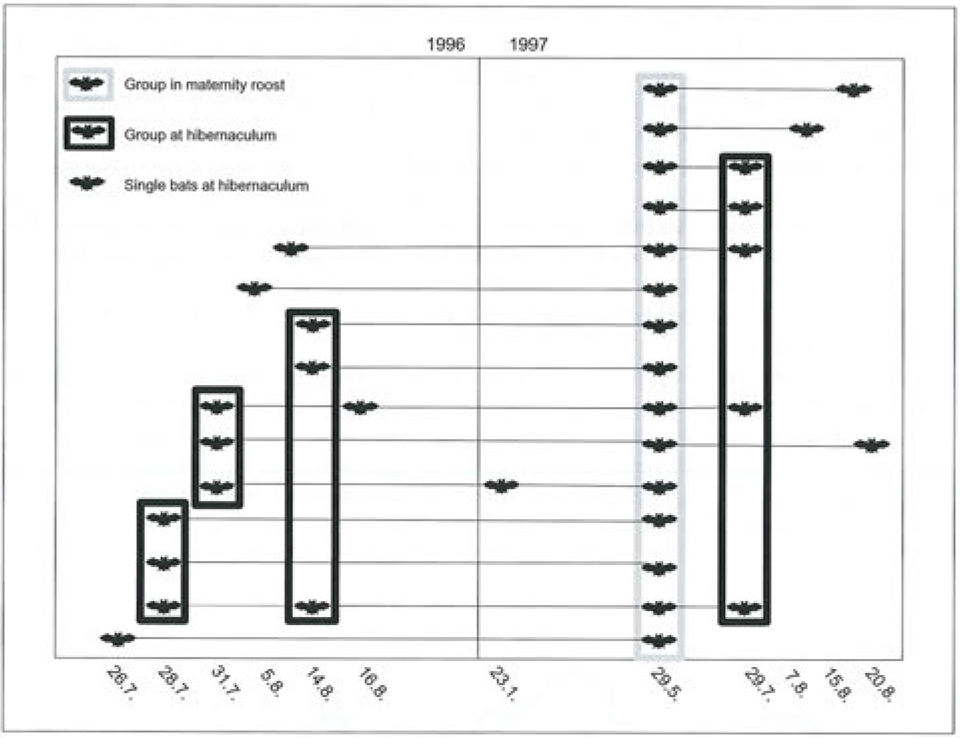

Figure 89: Example for the exploration in groups of the hibernaculum, taking as an example a common pipistrelle maternity roost colony from Lohra (at a distance of 12.6 km from hibernaculum).

6.4 Experiments in and at the hibernaculum concerning the roost locating ability of the common pipistrelle

In the hibernaculum of the Marburg castle, experiments were carried out concerning the common pipistrelles' roost exploration, behaviour. This place was chosen due to the fact that it is extremely frequented by common pipistrelles, and was therefore expected to provide enough observation data for evaluation, gained under natural circumstances. The intention was to investigate the roost exploration behaviour of the common pipistrelles as influenced by the surface structure of the roost entrance, by using eight different panels, each of two square meters in size (see figure 90). Four of the panels each had a smooth surface (synthetically layered), and four panels a rough one (pressed shaving, untreated). In each group (rough or smooth, respectively), there was a panel with a projection of 1.5 cm of depth, one with a projection and an additional gap (20 x 1.5 cm), one only with a corresponding gap, and one without any coarse structure (compare horizontal projection and profile in figure 90).

Two infrared video-systems were installed, in order to supervise the panels, so that a recording of the flight activities over several months was possible. The aim of this experiment was to find out, by registration of the approaches to the different panels, whether common pipistrelles react in a stronger way to certain structures, investigating them more intensely via frequent approaches. The results were to be considered for the new creation of

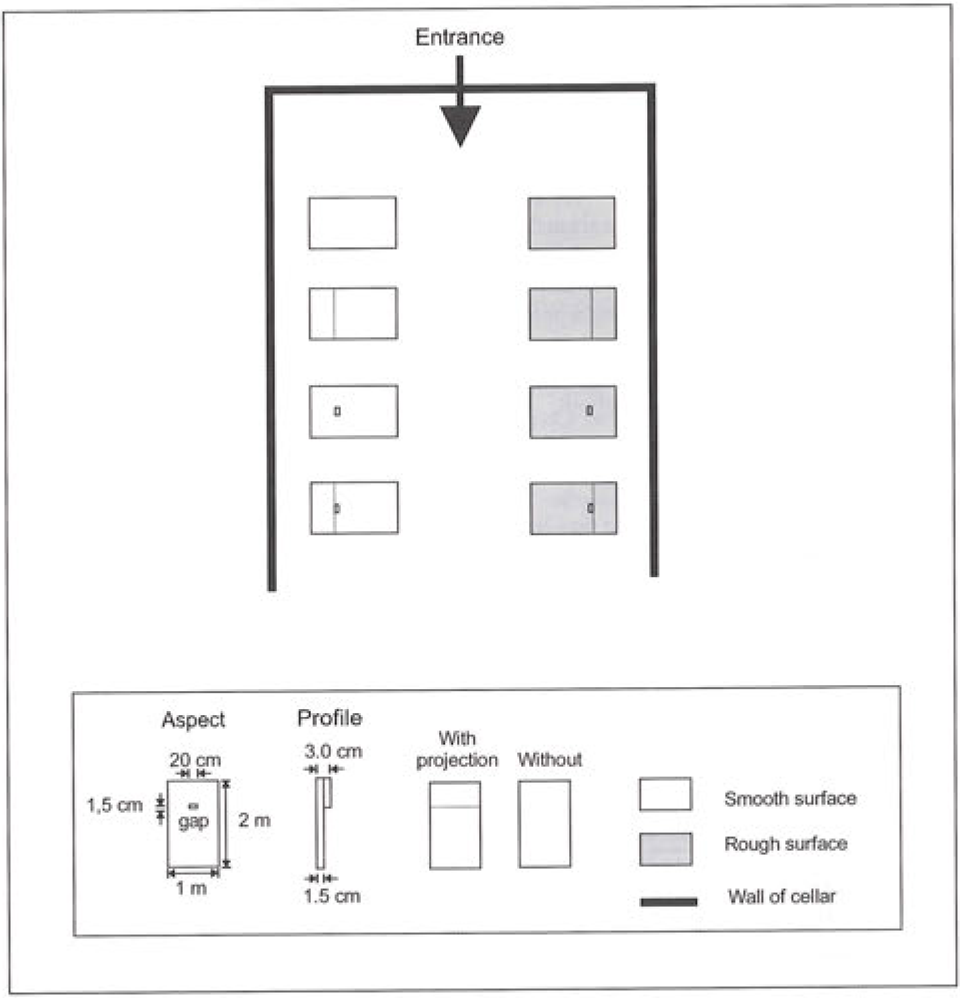

Figure 90: Draft of the experimental design for the investigation at the mass hibernaculum of the common pipistrelles' exploration behaviour. Above: aspect of a section of the vault with the only entrance possibility and the location of the panels. Below: dimensions and structure of the panels.

potential roosts, providing at the roost entrance the structures that are attractive for the bats, thus enabling them to find the new roost.

Seven observation nights could be evaluated at the panels with rough surfaces (each 1 h). In contrast, for the smooth panels there were only four observation nights. A total 355 approaches of common pipistrelles could be registered at the panels during this time. Both panel types (smooth and rough) were approached by the common pipistrelles. A major result was that there was a basic differentiation made between the smooth and rough panels: no difference in the approaching behaviour could be observed at the smooth panels, whereas at the rough panels significant differences were ascertained (univariate variance analysis, $p < 0,005$). The rough panels with projections were approached with a clear preference, in comwas carried out only during certain phases in summer, due to the quite high expense in evaluating the video tapes. Apart from providing behaviour observation, the video surveillance also tested the functionality of the ultrasound sensor, as such sensors can sometimes record rain or similar disturbances.

The above-mentioned surveillance methods used at the invasion site "Steinweg" proved that bats had already explored the exterior facade of the invasion site in May/June. These bats must have been adults. Therefore old animals show roost exploration behaviour at the invasion sites, as they do at the mass hibernaculum. The activities reach a maximum in August and September, and decrease drastically afterwards, so that in October, there is hardly any activity. Only with the beginning of frost in November and December echolocation calls are detectable at the invasion site again (see figure 92).

This seasonal phenology of the bats' activity at the invasion site clearly differs from the phenology of invasion incidents, that is, from the seasonal distribution of immigrations into living rooms, which occured mainly during the months August and September (RACKOW & GODMANN 1996). Unwelcome immigrations into living rooms could only be observed as an exception, sooner or later within the course of the year (compare RACKOW 2002). Therefore, the question rises why the immigrations into living rooms and other buildings take place mostly during the two above-mentioned months. Up to now, it has not been known that common pipistrelles can already be observed in the early summer at the invasion sites.

The density of activity at the invasion site corresponds highly with the activity at the mass hibernaculum of Marburg Castle. A comparison between the echolocation activity or the captures at the invasion site, and the light barrier incidents at the hibernaculum proves this high correlation (compare figures 92 and 93). Both swarming incidents are to a great extent dependent on temperature. Thus, it is shown that a quite similar and synchroneous behaviour takes place at both sites.

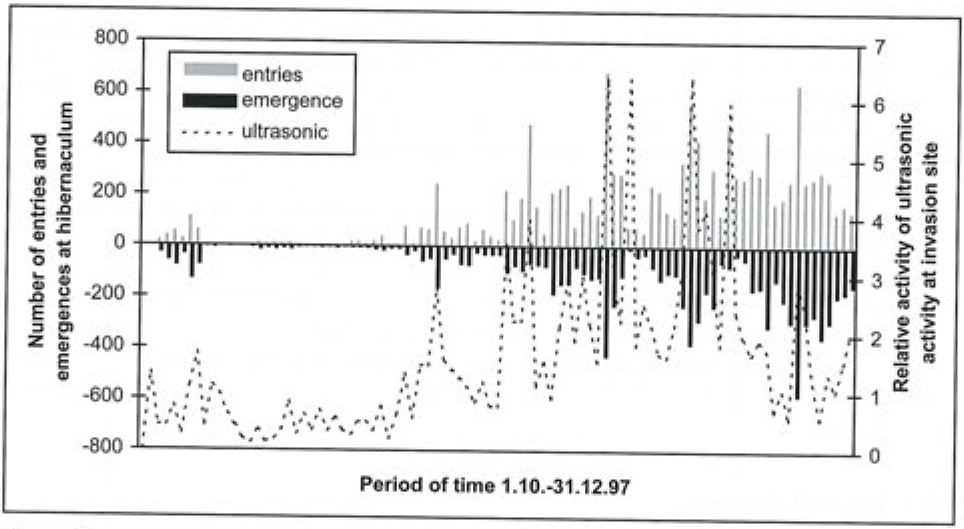

Figure 92: Relative activity of ultrasonic signals of common pipistrelles at the invasion site "Steinweg", in comparison to the numbers of entries and emergences at the hibernaculum in the Marburg Castle's vault (from SMIT-VIERGUTZ & SIMON 2000).

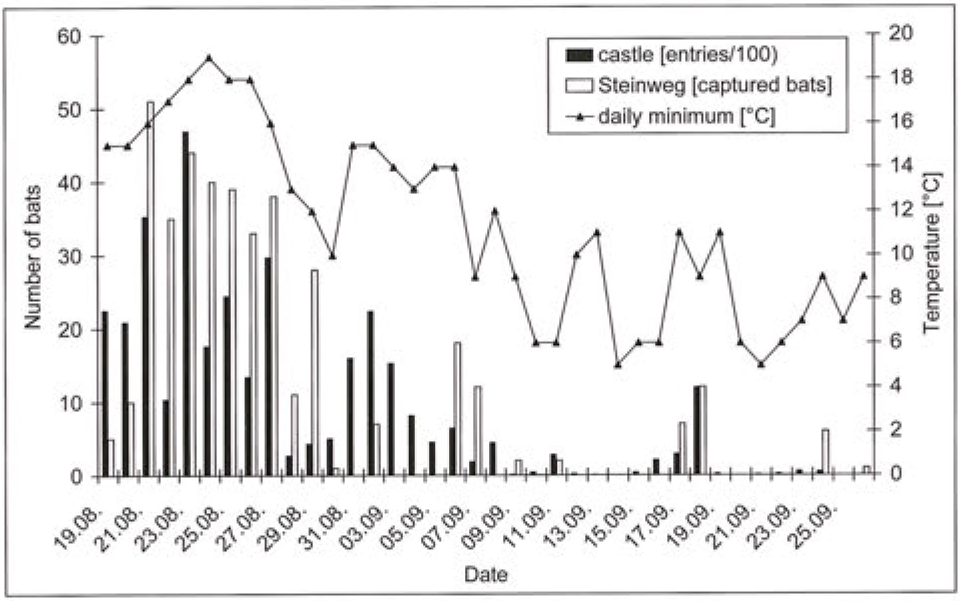

Figure 93: Number of captured common pipistrelles at the invasion site "Steinweg", in comparison to the numbers of entries and emergences at the hibernaculum in the Marburg Castle's vault (from SMIT-VIERGUTZ & SIMON 2000).

Composition of age and sex at invasions

Almost all invasion incidents by common pipistrelles are dominated by the young. Only in exceptional cases – outside the typical time for invasion which is the beginning of August to mid-September – are a greater amount of older animals to be observed. At the invasion site "Steinweg", the percentage of mature animals was relatively low (see figure 94). Otherwise, the percentage of adult bats can be 11 % on average (further invasion incidents at other sites in Marburg, with 550 individuals). Here, the percentage of adult animals decreases in the course of the invasion phase (SMIT-VIERGUTZ & SIMON 2000). During the "invasion period", the juvenile common pipistrelles also clearly predominate in the mass hibernacula. This has been ascertained in the Marburg Castle's vault, as well as in the hibernaculum in Korbach (see figures 87 and 95).

On 2nd September 1997, 69 common pipistrelles were captured with a net at the invasion site "Steinweg" (in a living room). Amongst them were 68 juvenile animals (43 females and 25 males), as well as one single adult male. During this season, almost exclusively juveniles are captured, even in the mass hibernacula. Amongst the 69 individuals, there were four from former invasions, which had been previously banded. Three of them, however, were banded in "Steinweg", which means that those animals appeared at least twice at the same invasion site. Therefore, the recapture proportion concerning the animals captured in "Steinweg" within one night was approximately 2 %.

When comparing all recaptures resulting from tube traps conducted in 1997 with the recapture rate from the netting, the proportion of recaptures was with only 0.69 % much lower (three recaptured individuals out of 433 bats).

Altogether, the recapture rate was therefore quite low and thus indicates a very high fluctuation during exploration amongst the common pipistrelles. For this reason, it must be expected

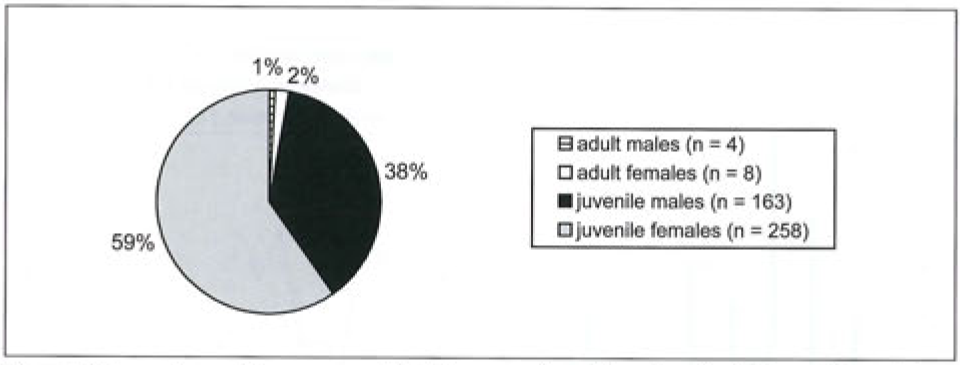

Figure 94: Age and sex of the common pipistrelles captured at the invasion site "Steinweg" (n = 433).

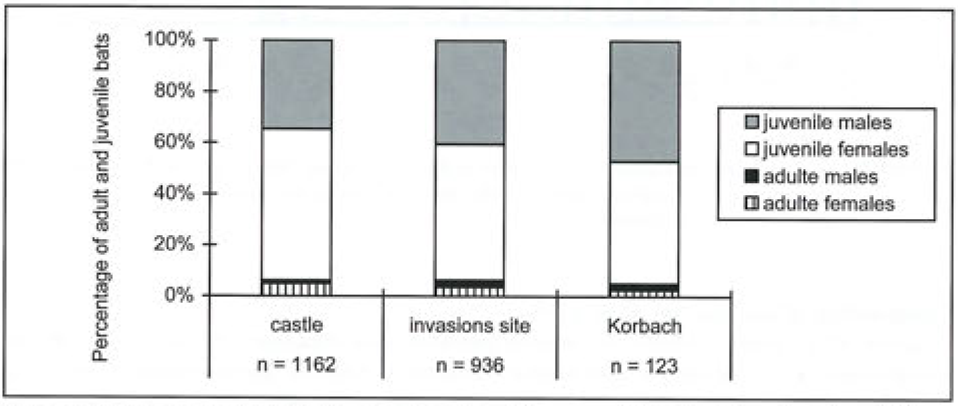

Figure 95: Comparison of relation between sex and age of common pipistrelles at invasion sites with those at the mass hibernacula of Marburg Castle and Korbach. The data were gathered in the months August and September of 1997.

that only 1–2 % of the animals visit the same invasion site at the summit of the invasion period. In this context, a further correspondence with the incidents at the mass hibernacula is evident, as during this season, an equally high fluctuation of animals can be observed there.

The method of "net capture" was employed only once at "Steinweg", and therefore was not selective, as the same conditions existed for already banded (captured with "tube trap") or non-captured individuals. The higher recapture proportion for "net captures" could therefore be expected, while for the tube trap a certain "learning effect" took place, due to the frequently repeated method. Animals which had got into the cotton bag, could learn that this is an unattractive place (concerning roost function) and avoid the tube trap in future.

Every invasion incident consists of mainly "new animals". Only few of them visit a second time. In addition, sometimes several big invasion incidents occur at the same locality or in the vicinity. This phenomenon indicates that there are big numbers of bats or big hibernacula in the vicinity, as many "new" common pipistrelles can only find invasion sites when they fly around within hearing of these sites. Equally high densities of common pipistrelles in areas of human settlement can only be expected near mass hibernacula.

6.5.2 Nocturnal phenology

The nocturnal explorations by bats at the invasion site generally start one or two hours after sunset. This is proved by recordings with ultrasound sensors, as well as by trapping exercises. The greatest flying activity was mostly registered after midnight. The explorations by common pipistrelles ended at dawn, at the latest.

6.5.3 Invasion sites are in hibernaculum towns and villages

The video recordings at the outside facade of the invasion site "Steinweg" led to essential insights, because with these recordings it could be observed that the animals approached the brick wall purposefully, sometimes landing, and then disappeared into crevices.

Approaches of common pipistrelles into open windows are generally not registered before August, at the summit of exploration behaviour (see above). At "Steinweg", the common pipistrelle flew mainly into the window, situated under the observed crevice roosts. But also other rooms of the flat were frequently visited, if any windows were left open.

In 1998 and 1999, the windows of one room at the invasion site "Steinweg", were kept open during the whole night in August and September. The common pipistrelles entered the room numerously on warm nights, and circled around the room several times. More detailed observations by video camera showed that the animals especially inspected the upper part of the room (see figure 96). This behaviour was used to capture the animals: a plastic tube, which had a cotton bag at its lower part, was fixed about 30 cm under the ceiling of a frequently approached corner (see figure 98). With this "trap" up to 51 individuals were captured in a

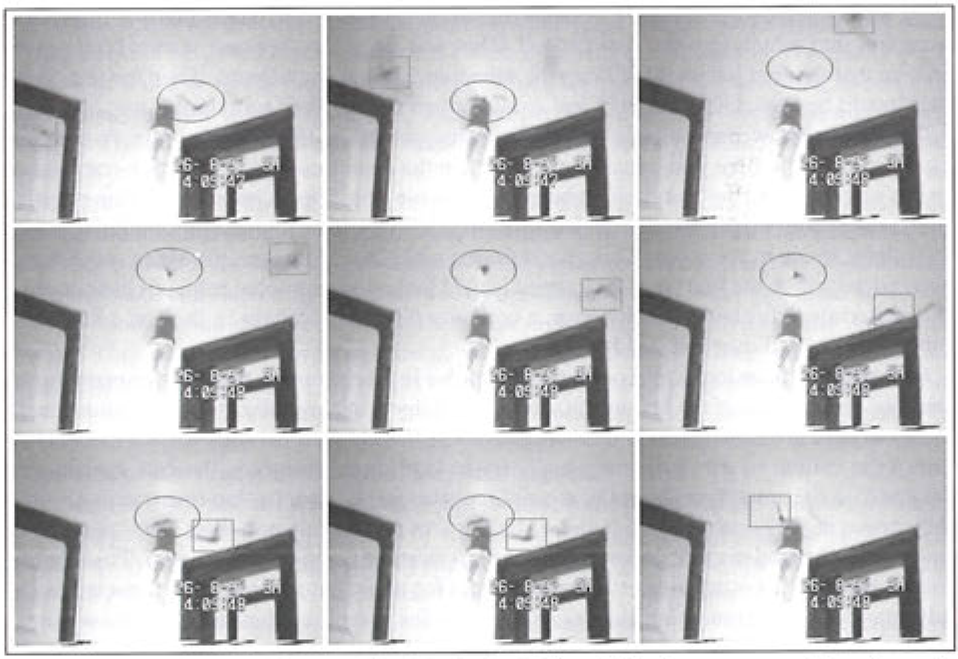

Figure 96: Photos from the video recording showing the flying activity of two common pipistrelles at the invasion site "Steinweg".

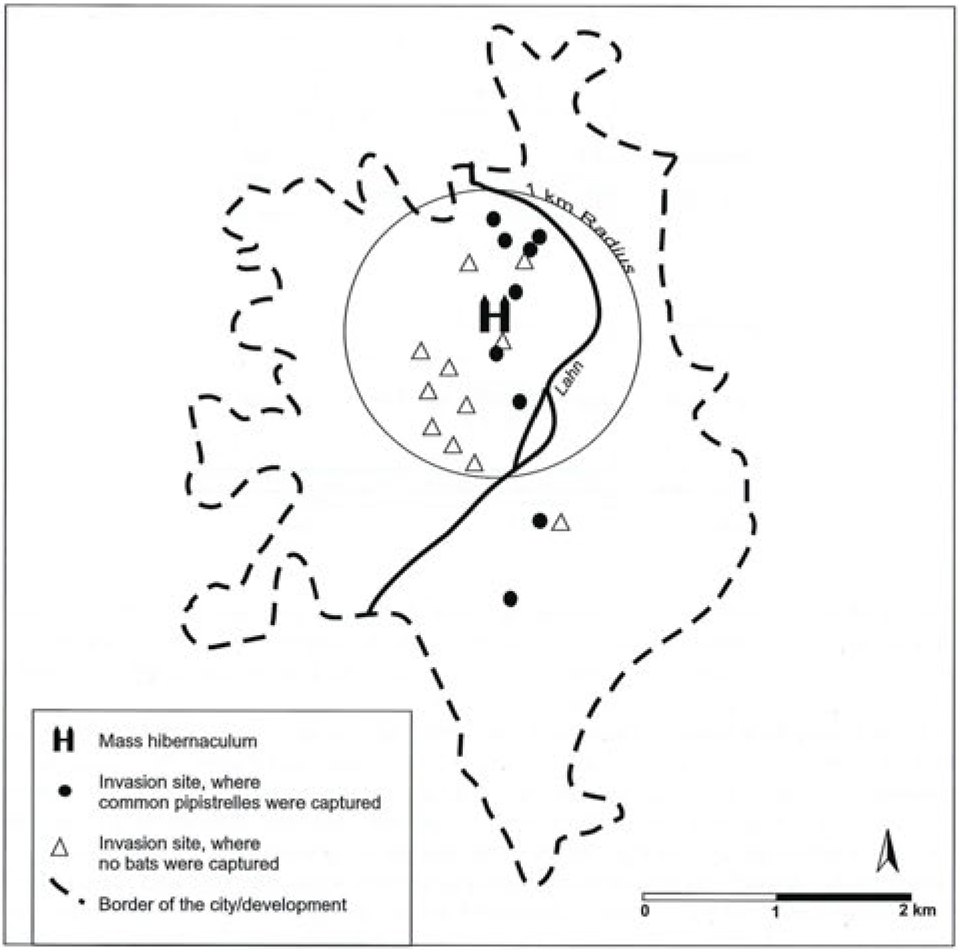

Figure 97: Location of common pipistrelle invasions sites in Marburg in 1997 (n = 20).

is not restricted to the hibernaculum, but that the animals search for adequate roosts in different villages. The extent of the summer exploration behaviour of the juvenile common pipistrelles becomes even more evident when the connections to the mass hibernaculum in the Marburg Castle is included. In 1997 alone, among the 1,000 common pipistrelles from the invasions were 65 individuals (see figures 102 and 103), which had been captured while exploring the hibernaculum before or after the invasion (thus about 6.5 %). It is remarkable that most of the bats were captured at the hibernaculum first and only afterwards recaptured at the invasion sites (see figure 103). This leads to the conclusion that the big mass hibernacula are explored earlier, and only afterwards in summer are the other smaller ones visited in the proximity of invasion sites. This can be explained by the fact that the large hibernacula are clearly swarmed around in early summer more intensively than the rest of the hibernacula, and therefore represent a greater attraction. In the further course of the summer as many additional hibernacula as possible – also near the invasion sites – are explored.

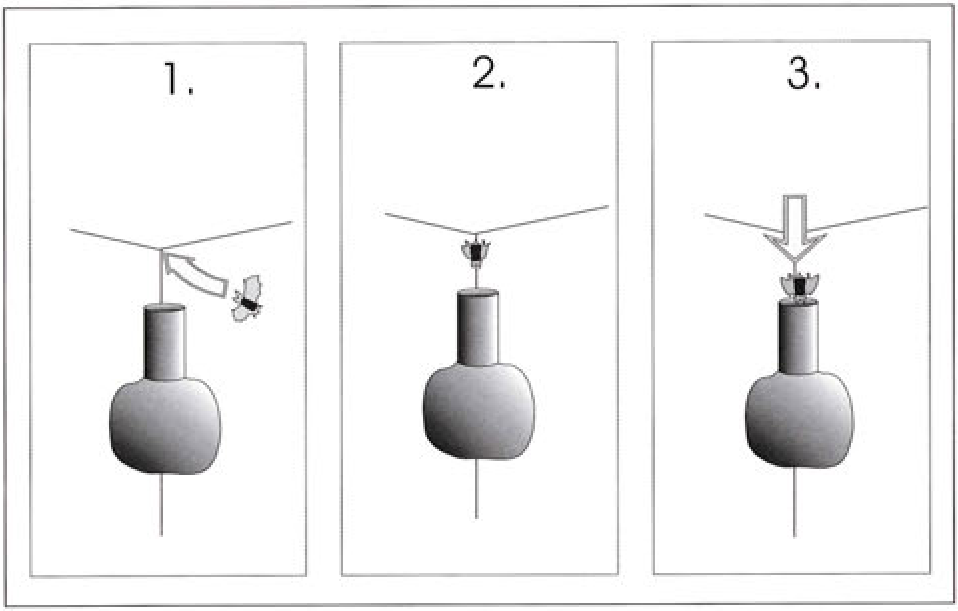

Figure 98: How the process of invasion was observed in a field experiment in the invasion site "Steinweg". 1. The common pipistrelles circle the room looking for places to hide and approach each corner, in this case a corner where a tube trap is erected. 2. The bat tries to land in the corner. 3. The bat cannot find a foothold and lets itself fall in order to fly off again, but in doing so lands in the tube trap because it cannot build up enough velocity in time.

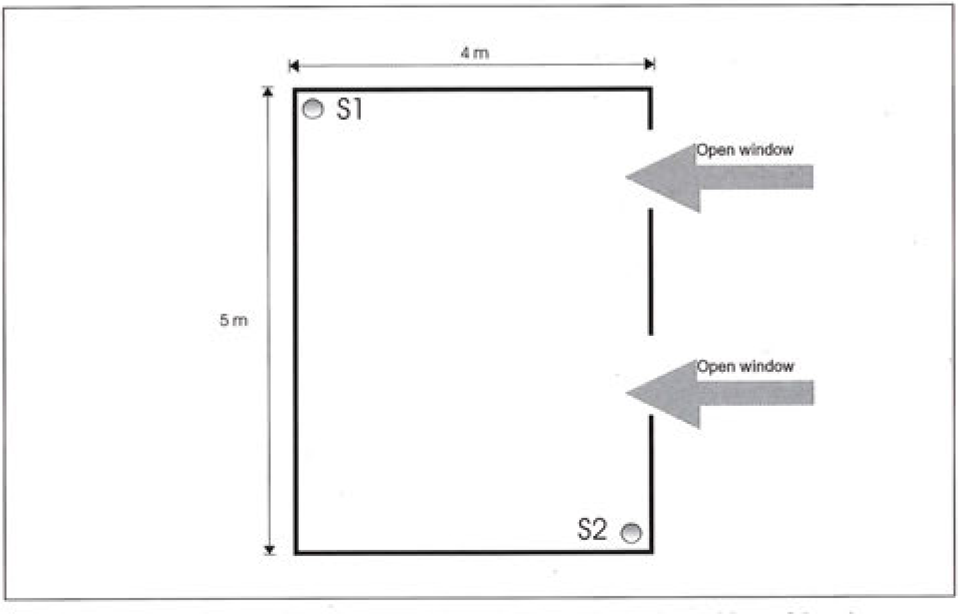

Figure 99: Plan of the room at invasion site "Steinweg". S1 and S2 are the positions of the tube traps.

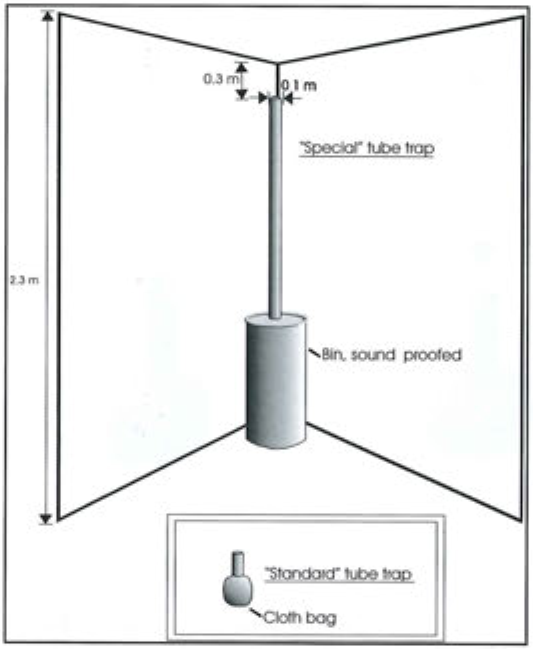

Figure 100:
Types of tube traps used to capture the common pipistrelles. Outline of the planned field experiment at invasion site "Steinweg".

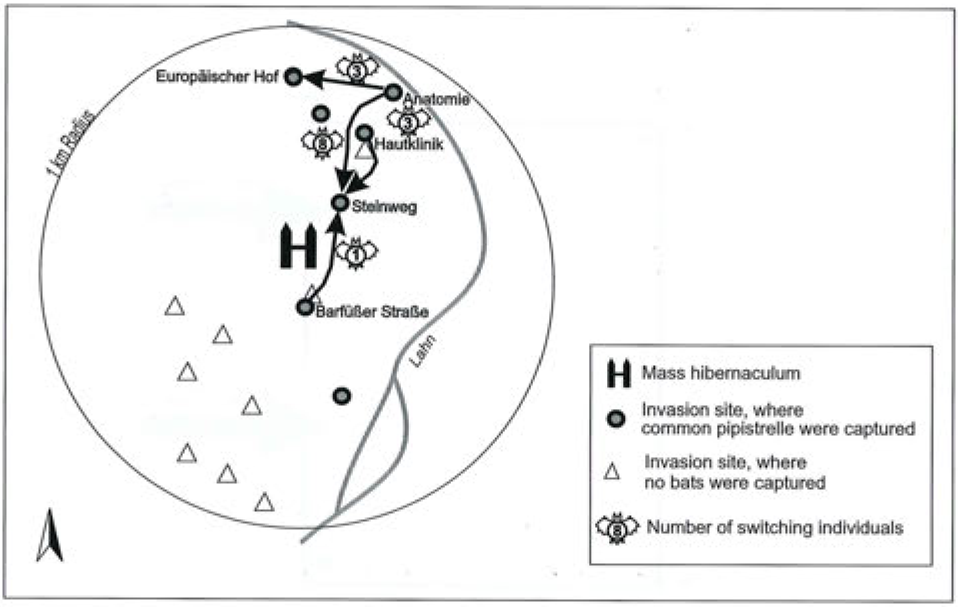

Figure 101: Switches between the invasion sites: recaptures of common pipistrelle individuals at different invasion incidents.

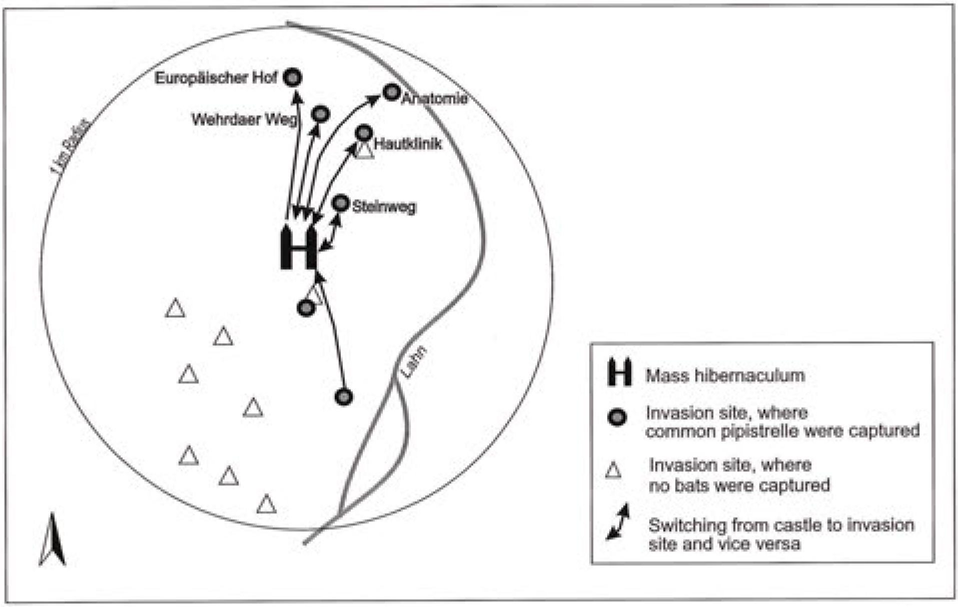

Figure 102: Switches between the invasion sites and the mass hibernaculum (Castle): recaptures of common pipistrelle individuals during swarming phase in the summer 1997 (July–September). The number of individuals and the banding sites can be seen in figure 103.

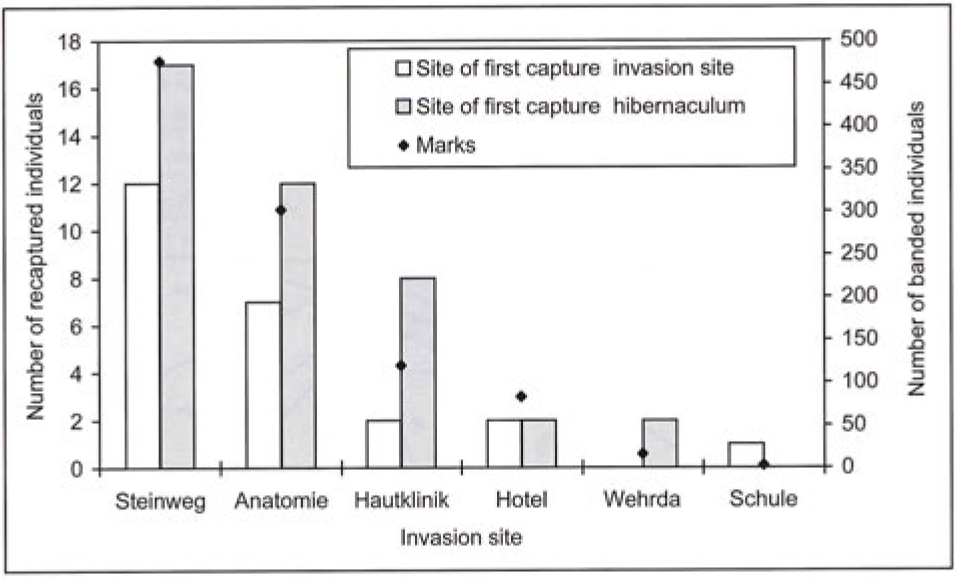

Figure 103: Quantitative representation of the summer switches between the invasion sites and the mass hibernaculum (n = 65): recaptures of common pipistrelle individuals during the swarming phase of summer 1997 (July–September). In addition, the number of banded common pipistrelles per invasion site is represented.

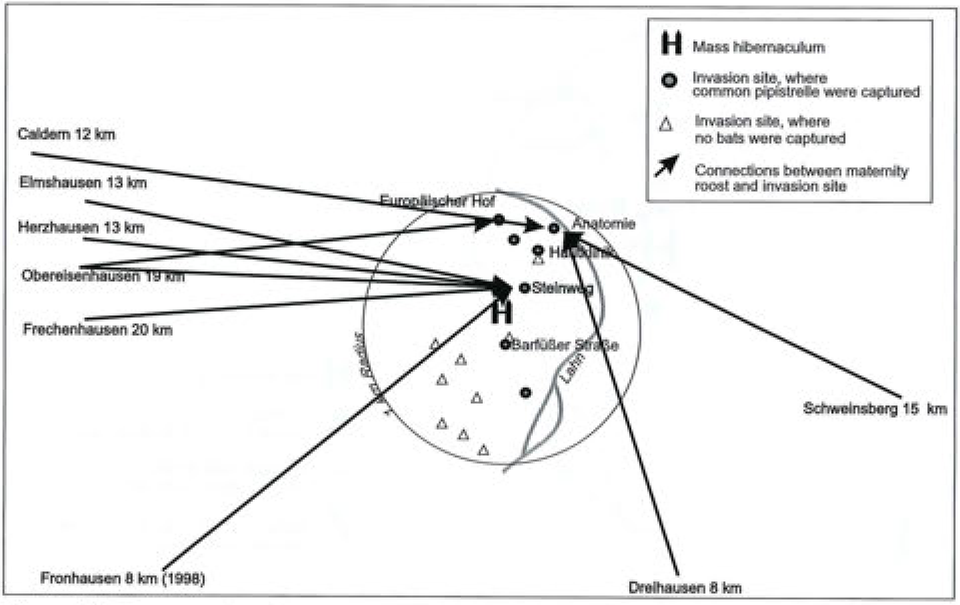

Figure 104: Representation of the proved summer switching of common pipistrelle individuals from the maternity roosts to the invasion sites in the year 1997 (exception: "switching" from Fronhausen to the invasion site "Steinweg" in 1998).

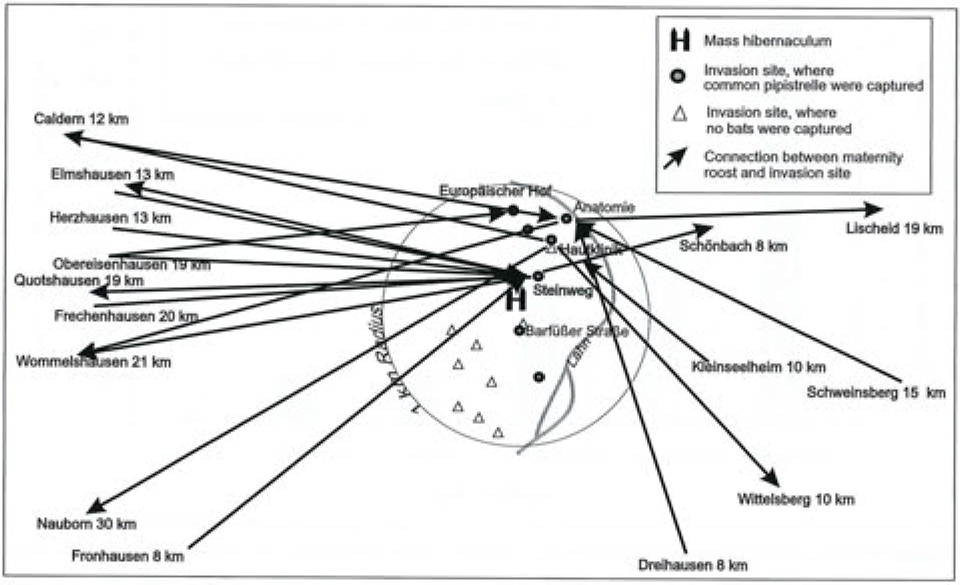

Figure 105: Representation of all proved switches of common pipistrelle individuals from the maternity roosts to the invasion sites and viceversa, in the years 1997 to 2000.

The number of recaptured animals at an invasion site evidently depends directly on the frequency of captures made there (see figure 103). Therefore, there doesn't seem to exist a preference for certain invasion sites and thus the common pipistrelles distribute themselves randomly around the town.

6.6 Swarming at the summer roost

Swarming at the summer roost means on the one hand the morning swarming at the roost before entering (e. g. SWIFT 1980). Thus, BÖHME & NATUSCHKE (1967) report about "test approaches" by Natterer's bats and greater mouse-eared bats at the entrances and emergences of a roost. NATUSCHKE (1960) has observed these test approaches in other species as well, as for example the common pipistrelle, Daubenton's bat, whiskered bat and serotine bat. Here, the animals approached the roost several times before entering or entered and emerged repeatedly. According to observations during numerous detector surveys within the project's framework, the morning swarming of a bat seems to have a luring effect on other bats that are passing by. This is especially important while the maternity colony is formating, around April/May. Furthermore, this kind of "information transfer" seems to have a special meaning for the bat species which switch roosts frequently. The question rose whether swarming is limited to the time in the morning shortly before entering the roost, or if there is also a nocturnal swarming or flying activity at the roosts. Insights to answer this question could be gained within the framework of the whole night-observations of the common pipistrelle and serotine bat.

6.6.1 Nocturnal activity of the common pipistrelle at occupied maternity roosts

The nocturnal activity at maternity roosts of the common pipistrelle was observed by spot checks at different roosts of one colony from May to July of one year.

At the beginning of the maternity period in May (pregnancy), only little activity could be detected after the animals emerged at night. Shortly before flying in in the morning, the greatest number of approaches could be registered within an interval of half an hour, with 478 approaches, although the roosts were occupied by 15 animals (see figure 106). Especially while maternity roost assemblages are formed, the morning swarming activity at the roosts is high, as the animals first need to "find" each other and gather together. During lactation in June, the roost was used by 38 animals. The peaks of the nocturnal activity occurred three, five and eight hours after sunset (see figure 107). The first two activity peaks indicated that the animals returned to the roost to suckle the young. The third peak developed during morning swarming in front of the roost: a particularly high number of approaches by the animals could be registered at the beginning of July, when the young were newly volant (see figure 108). The additional, equally high numbers of emergences indicated a frequent entering and emerging of the young as a typical behaviour of exploration. Then, the activity decreased until the dissolution of the maternity roosts (see figure 110).

6.6.2 Nocturnal activity of the common pipistrelle at unoccupied maternity roosts

Parallel to the observation of the nocturnal activity at occupied roosts, a maternity roost which had been occupied by up to 61 bats in 1998 was continuously observed with a video camera from May 12th to August 10th. Here it was found that the roost was not occupied during this time. Despite this fact, bat activity could be detected regularly at the roost, especially

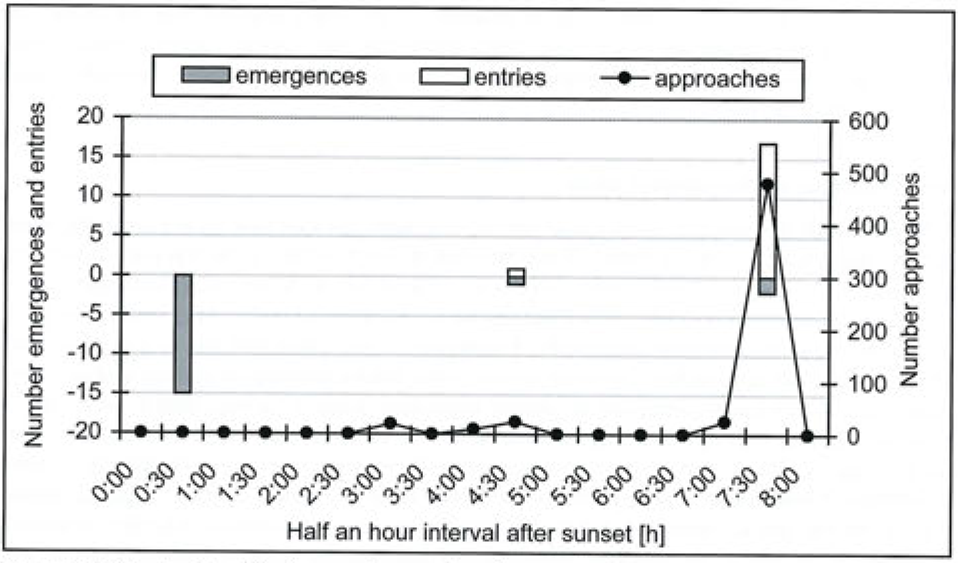

Figure 106: Nocturnal activity (approaches, entries and emergences) at a maternity roost of the common pipistrelle at time of pregnancy (13. 5. 1999). The roost was occupied by 15 bats.

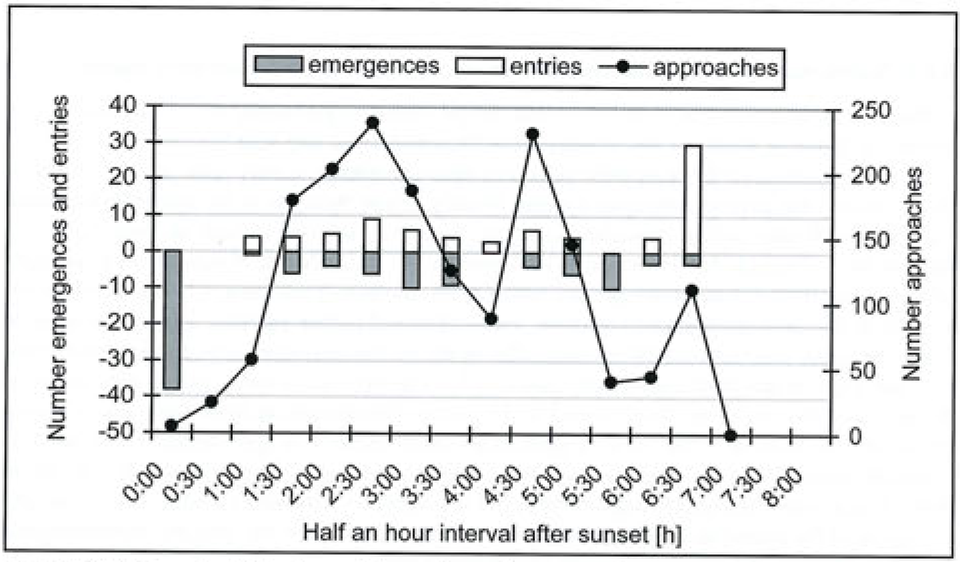

Figure 107: Nocturnal activity (approaches, entries and emergences) at a maternity roost of the common pipistrelle at time of lactation (19. 6. 1999). The roost was occupied by 38 bats.

in May, when maternity roost assemblages were being formed (see figure 111). This indicated that the bats approach already known roosts at the beginning of the maternity period, and check if there are any animals in the roost. Then they leave the roosts which are unoccupied in order to choose one that is.

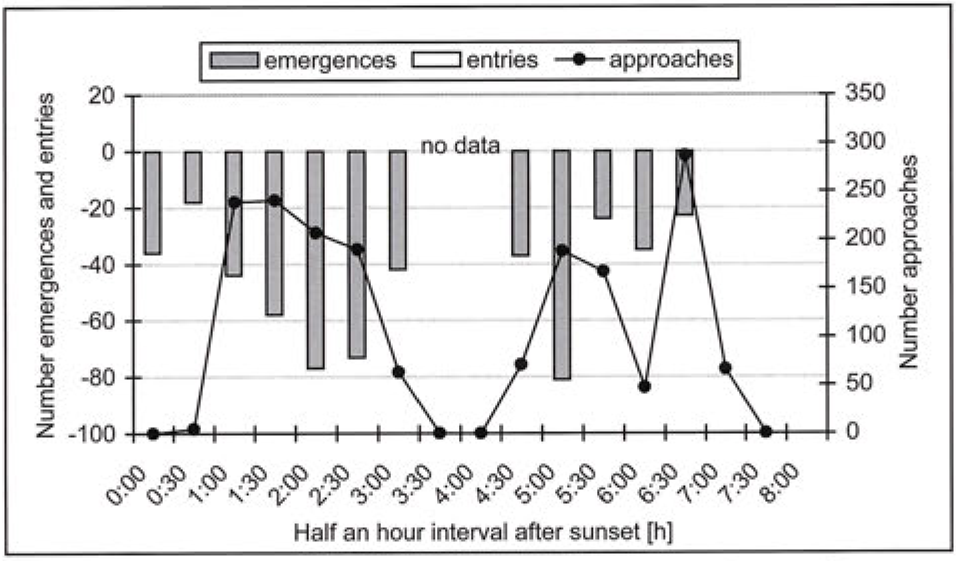

Figure 108: Nocturnal activity (approaches, entries and emergences) at a maternity roost of the common pipistrelle when young are newly volant (5. 7. 1999). Due to the fact that bats entered and emerged numerously and quickly one after another, the number of bats that spent the day in the roost cannot be given.

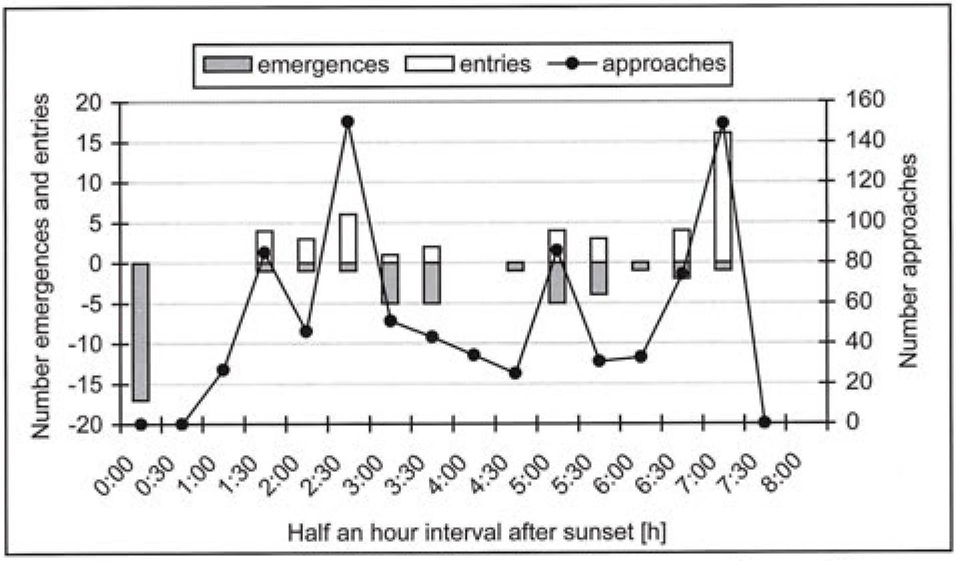

Figure 109: Nocturnal activity (approaches, entries and emergences) at a maternity roost of the common pipistrelle at time of post-lactation (14. 7. 1999). The roost was occupied by 17 bats.

A similar pattern of search was also shown during time of pregnancy and lactation. The peaks of activity at an unoccupied roost were more or less parallel in time to the activity in occupied roosts (see figure 112). During the pregnancy period, the greatest activity could be

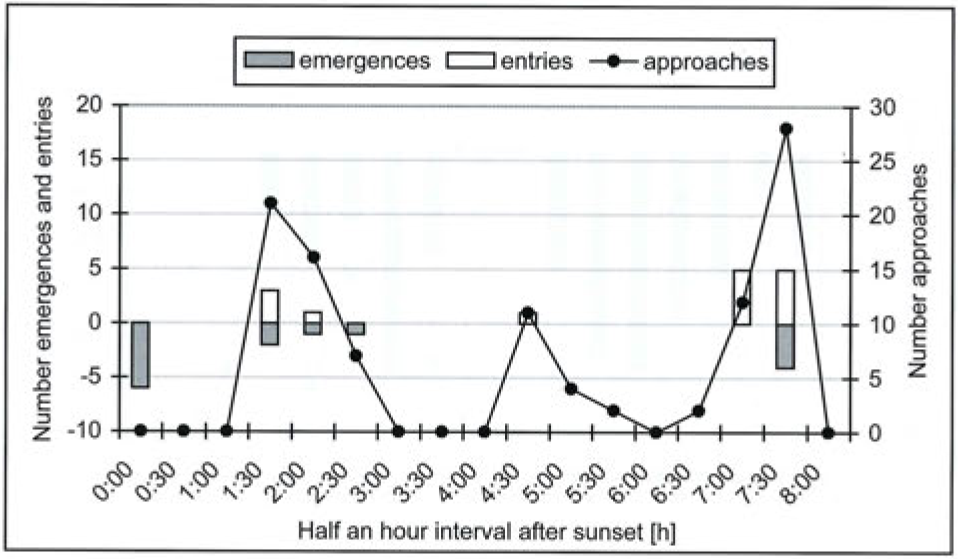

Figure 110: Nocturnal activity (approaches, entries and emergences) at a maternity roost of the common pipistrelle when the maternity colony was dissolving (19. 7. 1999). The roost was occupied by 6 bats.

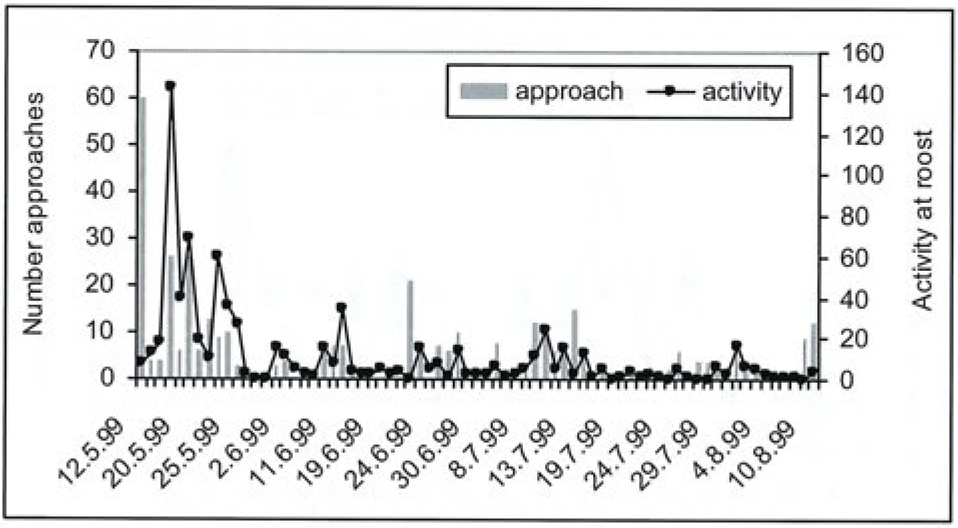

Figure 111: Nocturnal activity (= swarming and circling) and approaches to a maternity roost of the common pipistrelle, which was unoccupied in 1999, between the 12th of May and the 10th of August. The roost had been occupied by up to 61 bats a year ago.

detected while the bats were entering the roost in the morning, regardless of whether the roosts were occupied or not. However, at the unoccupied roosts, flying activity could be observed also during the night. At the time of lactation the peaks of activity at both occupied and unoccupied roosts are between 2 h to 3 h after sunset and between 4 h and 5 h after sunset. (see figures 107 and 112). During the post-lactation period of the maternity colony, activity could be registered the whole night through (see figure 113). However, here the quantity of activity was much lower at the unoccupied roosts than at the occupied ones (see figure 114).

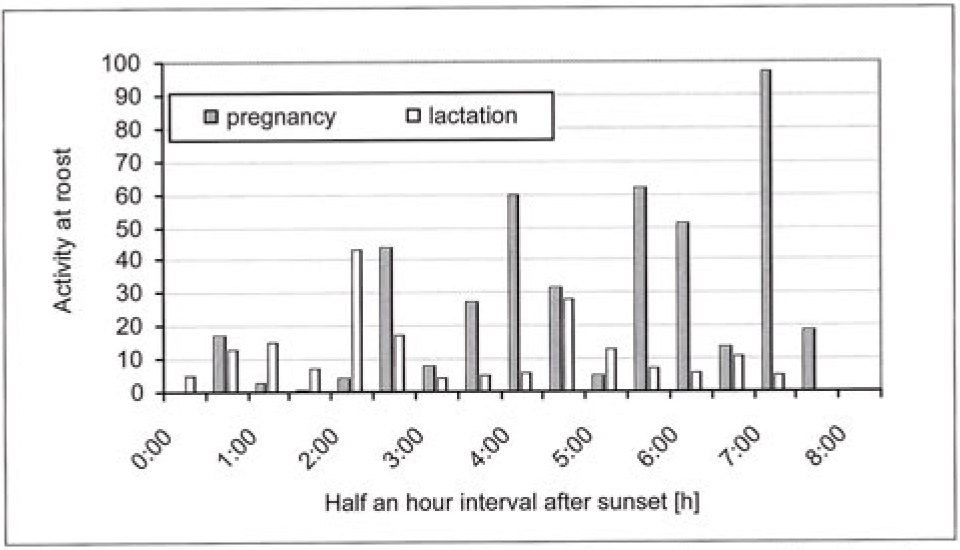

Figure 112: Sum of nocturnal activity (circling) at an unoccupied maternity roost during time of pregnancy and lactation.

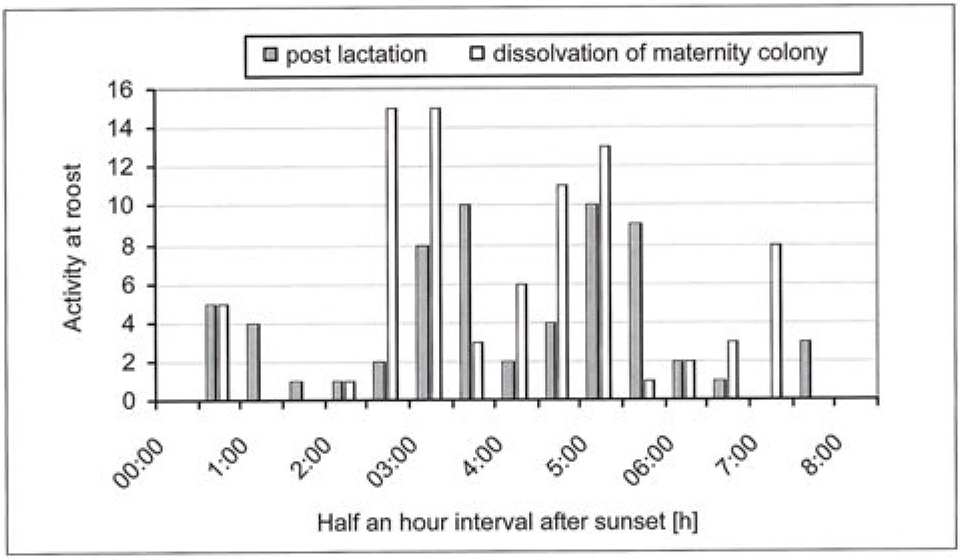

Figure 113: Sum of the nocturnal activity (circling) at an unoccupied roost during time of post-lactation and after the maternity colony has dissolved.

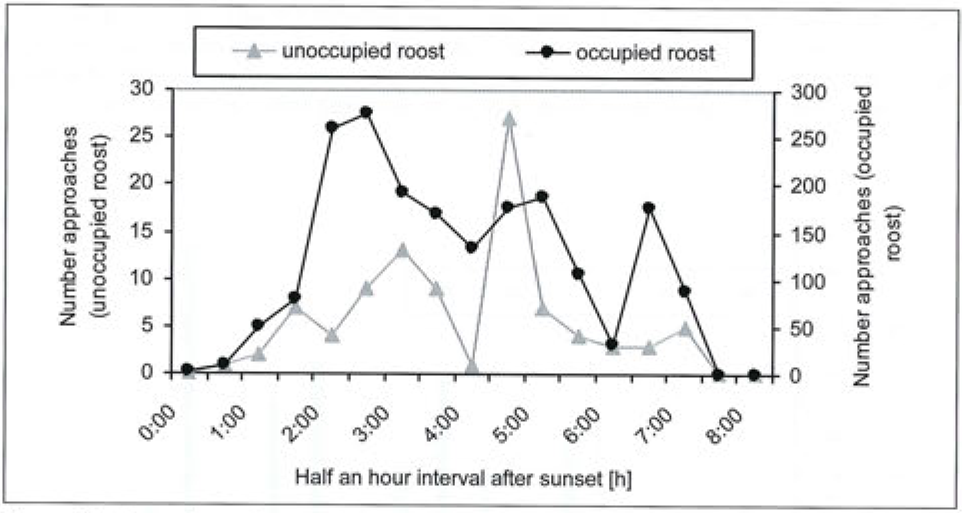

Figure 114: Comparison of nocturnal activity (sums) between occupied maternity roosts and an unoccupied common pipistrelle roost.

6.6.3 Nocturnal activity of the serotine bat at a roost complex

The nocturnal activity of the serotine bat was investigated at a building which has a roost complex of 123 crevices above the windows (see chapters 3.1.6 and 7.2.2.1). Apart from entries and emergences, also approaches, flights past the roosts and circling of the bats were registered. In the course of the night there are three activity peaks (see figure 115). At the beginning of the night mainly emergences, but also flights past the roost, took place. The second peak was registered between 10:30 p.m. and 0:30 a.m. Here, flights past the roosts pre-

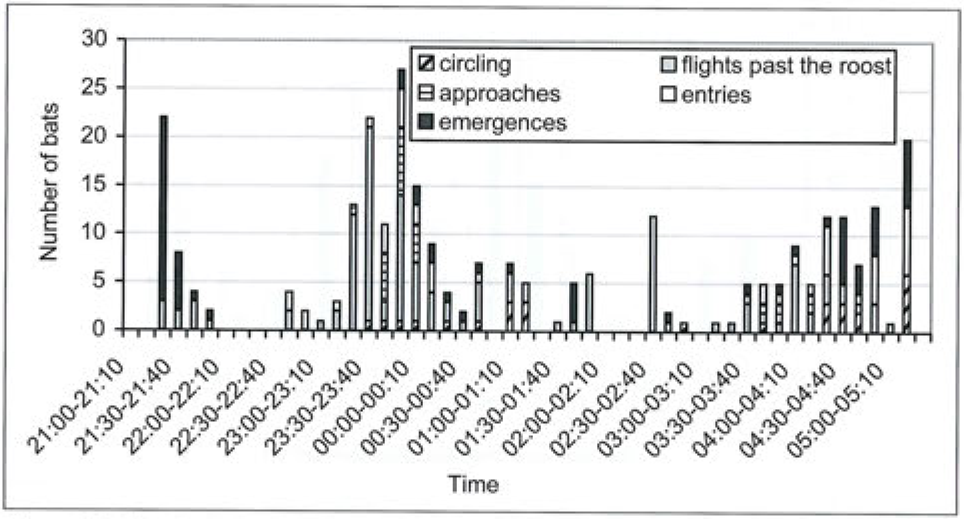

Figure 115: Nightly activity of the serotine bat at a roost complex.

dominated, followed by approaches. In addition, the first serotine bats were entering again. The third peak was between 4:00 a.m. and 5:00 a.m., consisting of entries, but at the same time also of numerous emergences. In comparison to the common pipistrelle, which showed a strong swarming behaviour at this point, only few approaches by serotine bats could be registered. Instead, for this species, entering and emerging in the early morning hours seemed to play an important role in keeping the maternity roost assemblage together.

In one night, serotine bats used up to six different roost crevices (see figure 116). Half an hour after emergence, a great number of animals entered the same roost again. Towards morning, animals could be observed emerging, which indicates a roost switch (compare chapter 7.2.2).

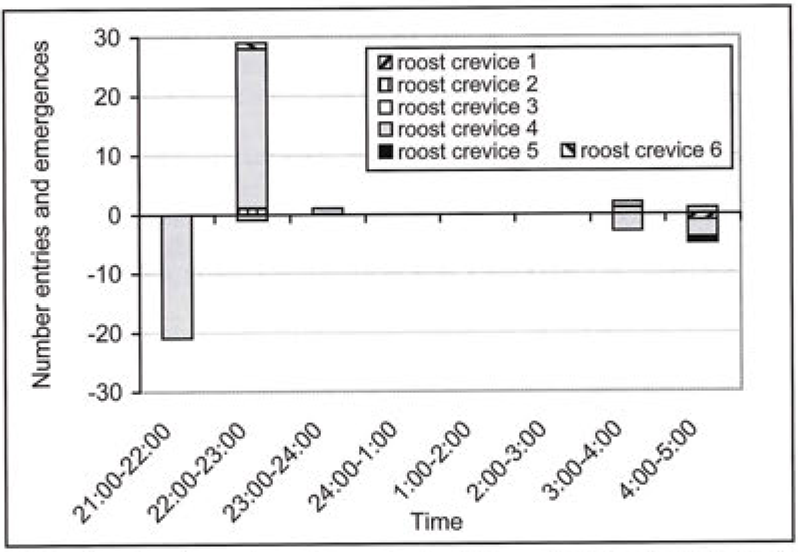

Figure 116: Number of entering and emerging serotine bats at a roost complex. In one night, six different roost crevices were used.

6.7 Summary

Swarming at the hibernaculum

- The common pipistrelle's activity of entering and emerging in autumn, winter and spring, as well as the swarming activity in summer is definitely dependent on the temperature.
- The results about the phenology of the common pipistrelle's flight activity at the Marburg hibernaculum could be proved at a further hibernaculum in Korbach.
- Through light barrier balances, 5,000 hibernating common pipistrelles could be determined in the Marburg castle. However, the number of common pipistrelles taking part in the summer swarming, and which could be calculated by banded animals, was approximately 20,000–30,000.
- During the summer swarming, a certain phenology concerning age and sex of the common pipistrelles can be determined. From early summer to mid-July, almost exclusively adult males, and some females not reproducing that year, swarm at the hibernaculum. In July, more and more adult females from the maternity roosts appear. By the end of July the first

young of the year can be observed in the hibernaculum. At this time, the old males have mostly disappeared. By mid-August, the proportion of young ones increases more and more, until there are only young animals left swarming.

- The adult females seem to "show" the hibernaculum to the young.
- The average time of stay while swarming at the Castle's hibernaculum, was about 6 minutes for the old males and about 10 minutes for the young and the old females. During the exploration, the animals purposefully approach crevices in the walls, partly disappear into the crevices for a short time and then crawl out again.
- By means of the individually banded common pipistrelles, numerous spatial relationships between colony villages and the Marburg hibernaculum could be verified through targeted recaptures. The common pipistrelles come from a surrounding radius of up to approximately 40 km.
- The common pipistrelles return to their colony village immediately after exploring the mass hibernaculum, and spend the day there. Distances of up to 22 km are thus covered. Presumably the animals fly to the hibernaculum and return to the colony village within one night.
- Through banded common pipistrelles, it could be shown that some animals from one maternity colony explore the hibernaculum together in one night.
- Common pipistrelles explore the roosts according to a certain search criteria. In an experiment, common pipistrelles favoured rough surfaces with a small 1.5 cm high projection for their approaches. This means that projections should be fixed above the roost openings when new roosts are created.

Invasions

- The localities where invasions occur also hold hibernacula which are reconnoitred in summer.
- Exploration or swarming is already detectable from May onwards, which means that adults also swarm at invasion sites.
- However, invasion incidents only take place from August on, when inexperienced young "have an accident". As these animals attract other animals with their calls (proved by experiment), a great number of common pipistrelles happen to accumulate at the invasion sites.
- Mature animals presumably have much less "accidents", due to their better knowledge of the hibernacula, which they approach in a more purposeful way. Despite a high swarming activity of adult females at the invasion sites, there are virtually no invasions in July.
- Specific exploration behaviour provokes "accidents".
- When many animals "have accidents" together, the invasions predominantly occur near hibernacula.
- By means of banded common pipistrelles, it could be proved that the mass hibernaculum and also several invasion sites were explored over the same summer.
- Those animals seen at invasion sites came from the neighbouring colony villages at distances of up to 35 km.

Swarming at the summer roost

- At dawn the common pipistrelles present the highest swarming activity in front of the roost. Swarming behaviour endures over the whole summer, but reaches its summit during the time maternity colonies are formed.
- Serotine bats do not present the classical, morning swarming behaviour, but emerge the roost repeatedly at dawn and enter the roost without circling conspiciously.

- During the lactation period, three activity peaks could be observed at occupied common pipistrelle roosts.
- There was also a high activity during the summer at an unoccupied common pipistrelle roost. The periods of maximum activity coincided with the ones at occupied roosts.

7 Spatiofunctional relationships

7.1 Introduction

Bats have different relations to the spatial elements of their environment according to the functions of these locations. They are assigned here to different levels. The first level (level 1) is the roost assemblage of the house-dwelling species. The next level is the relationship between summer roosts and foraging sites. Apart from the distance between the maternity roosts and the foraging sites, statements will be made here – where possible – about home ranges, the use of foraging sites and other use of roosts. On the third level, the bats' summer switching of villages over larger distances will be analysed. This level includes specific recaptures in maternity roosts and the results of radio-tracking bats. The longest distances are analysed on the fourth level, namely the spatial relationship between the summer roosts and the hibernacula. In addition to specific recaptures in both types of roosts, long-distance discoveries (incidental discoveries) are also considered.

7.2 Summer roost assemblage (level 1)

LEWIS (1995) has evaluated statements concerning roost switching and the roost fidelity of 43 species of bats from all over the world, among them the greater mouse-eared bat as the only species from Germany. The basic hypothesis of LEWIS is that the roost fidelity of one species depends on the type of roost. There are so-called durable, long-lasting roosts like caves and buildings which are rarely changed by their inhabitants. On the other hand, short-lived, transitory roosts like tree-hollows, foliage and cracks in bark lead to a frequent roost switching of the bat species. In all, 25 of the 43 species evaluated by LEWIS (1995) belong to the frequent roost switching species. Fourteen species only change their roosts rarely and 4 bat species show a certain variability within their species. The greater mouse-eared bat is classified by LEWIS (1995) as a house-dwelling species with a certain roost fidelity. The application of LEWIS' (1995) basic hypothesis to all species of bats is questionable. Among the house-dwelling species in Germany can be found both frequently roost switching bat species (common pipistrelle, serotine bat, whiskered bat, barbastelle bat) and species which are more likely to change their hanging place than their roost such as the greater mouse-eared bat and the lesser horseshoe bat (*Rhinolophus hipposideros*).

LEWIS (1995) lists 8 possible functions or possible reasons for roost switching behaviour presented by different authors:

1. Reaction to disturbance, e. g. by humans (KUNZ 1982);
2. Avoiding enemies (KUNZ 1982, WILKINSON 1985 in LEWIS 1995);
3. Proximity to the foraging site (FLEMMING 1988 in LEWIS 1995, KUNZ 1982);
4. Avoiding ectoparasites (FLEMMING 1988 in LEWIS 1995, LÖHRL 1953 in LEWIS 1995, WILKINSON 1985 in LEWIS 1995);
5. Avoiding bad microclimate or structural conditions in the roost (FLEMMING 1988 in LEWIS 1995, KUNZ 1982);
6. Avoiding piles of excrements and associated pathogenes in the roost (STRATMANN 1978 in LEWIS 1995);
7. Transmission of knowledge about roosts and foraging sites to the juveniles that become newly volant (WOLZ 1986); and
8. Reduction of energy consumption on cold days in a suitable roost (AUDET 1990).

The aim here is not to explain exhaustively the possible causes for roost switching behaviour. The intention is rather to explore this phenomenon in detail and quantitively for most house-dwelling species, with emphasis on the following questions:

- Which bat species switch roosts?
- How often do they switch?
- How many roosts are used within one year?
- How far is the next roost?
- Are there roosts which are used repeatedly every year?
- Do only certain individuals switch roosts?

7.2.1 Common pipistrelle

Investigations into the nursery colonies of the common pipistrelle are published frequently. Many authors have examined the emergence behaviour at the maternity roost (e. g. AVERY 1986, BULLOCK et al. 1987, SPEAKMAN et al. 1992, SPEAKMAN 1993, SPEAKMAN et al. 1995, SPEAKMAN et al. 1999, WILHELM 1971). The previous approach was confined throughout to the examination of particular roosts or to different separate nursery colonies. In this way, THOMPSON (1992) has examined 26 nursery colonies over 11 years. However, he has put the main emphasis on the changing of individuals between the colonies within the study area of 500 km^2 and on the roost fidelity which was demonstrated in four intensively examined colonies. There are no analyses of the roost switching behaviour of the common pipistrelle. OHLENDORF (1983) reports on a continual change of common pipistrelles between two roosts that were situated 40 m from each other which happened in mid-July on successive evenings. NATUSCHKE (1960) reports on spontaneous roost switching shortly before the time of birth. HURKA (1966) does not mention roost switching behaviour, but he makes a distinction between a maternity roost (used from May until late in August) and an intermediate roost (used in spring and autumn). LANG (1996) who examined four roosts of the common pipistrelle in London, reports only indirectly on roost switching behaviour. The common pipistrelles were temporarily not to be found in their roosts which meant that they used at least one further unknown roost.

7.2.1.1 Spatial examination of the roost assemblage

During the years 1998–2000 a total 29 maternity roosts of the common pipistrelle could be found in the village of Kleinseelheim (area: 0.2963 km^2, 257 buildings). The roosts were almost all situated in the old centre. It can be demonstrated that the nursery colony of the common pipistrelle in Kleinseelheim used at least 16 roosts per annum.

A total 83 % (n = 45) of the adult female bats banded in 1998 in Kleinseelheim were recaptured during the investigation years 1998–2000. These 45 common pipistrelles carried out 120 cases of roost switching within 9 maternity roosts (see figure 117). Another three maternity roosts were also temporarily used but not counted here due to methological reasons.

Twenty-five maternity roosts of the common pipistrelle were found during the years 1997–2000 in the larger village Wittelsberg (size: 0.6708 km^2, 340 buildings). The roosts were situated in two different areas of this long stretched-out location and not only in the small older centre as in Kleinseelheim. In this location the common pipistrelles used up to at least 14 roosts per annum.

69.3 % (n = 61) of the adult female bats banded in 1998 were recaptured during the years 1998–2000. The banded females made a total 108 roost switches within 12 maternity roosts

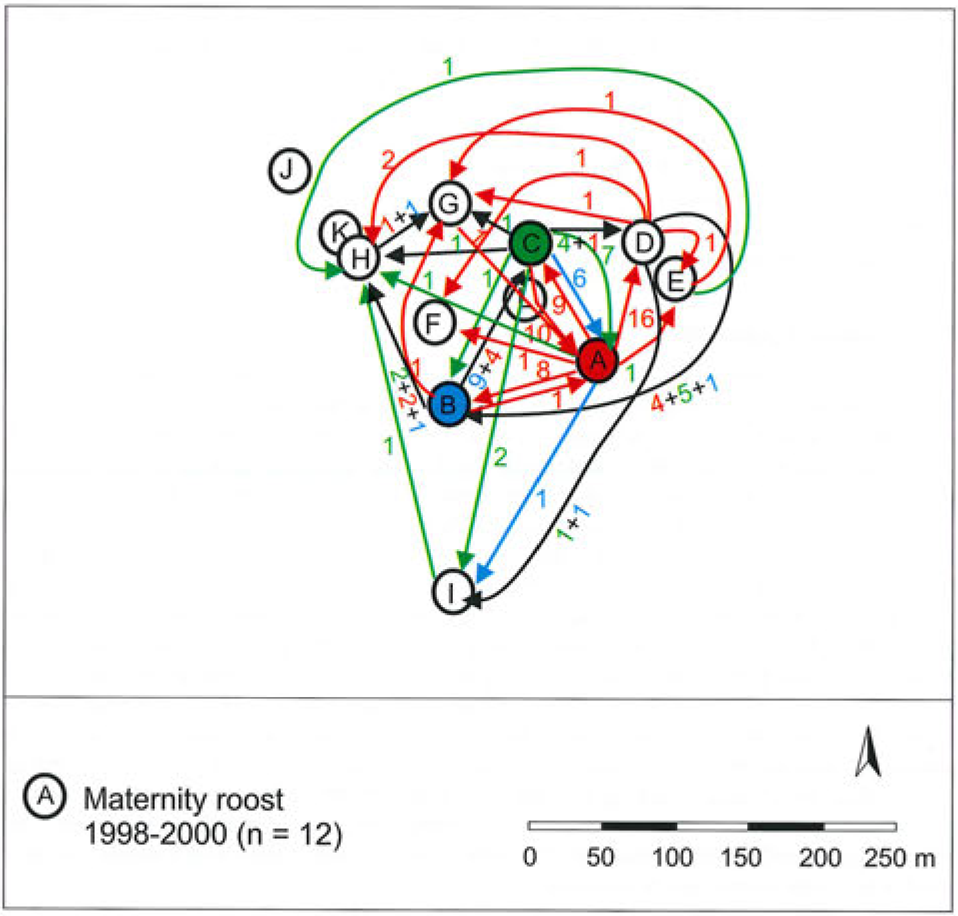

Figure 117: Diagram of roost switching behaviour of the common pipistrelle banded in 1998, proven by mark and recapture, during the years 1998–2000 in Kleinseelheim. The different colours of arrows and numbers refer to the place of first capture (maternity roost [MR] with corresponding colour) of the switching individual.

(see figure 118). It is notable that in Wittelsberg the roosts are in two different areas of the village (two groups of roosts). Additionally, the number of roost switches between the nearby maternity roosts was much higher than between the distant roosts. If the female bats of the two groups of roosts are allocated to so-called "sub-colonies", then there were in all 172 cases of roost switching within the sub-colonies and only 36 cases between the sub-colonies (see figure 119). The roosts within these so-called sub-colonies are a maximum 158 m apart. In contrast, the average distance between the roosts of the two sub-colonies is 533 m (see figure 120).

Spatial delimitation of the roost assemblage

Comparing the average distances between the maternity roosts in Kleinseelheim and Wittelsberg, it is obvious that the average distance of 157 m between the roosts in Kleinseelheim

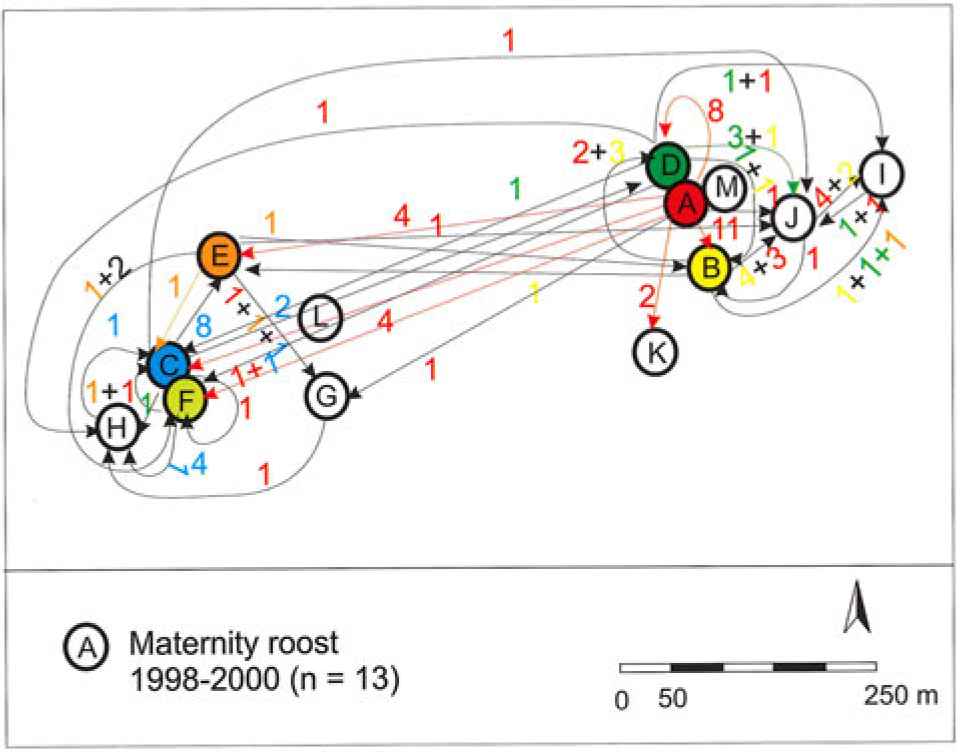

Figure 118: Diagram of roost switching behaviour of the common pipistrelles banded in 1998, proven by mark and recapture, during the years 1998–2000 in Wittelsberg. The different colours of arrows and numbers refer to the place of first capture (maternity roost [MR] with corresponding colour) of the switching individual.

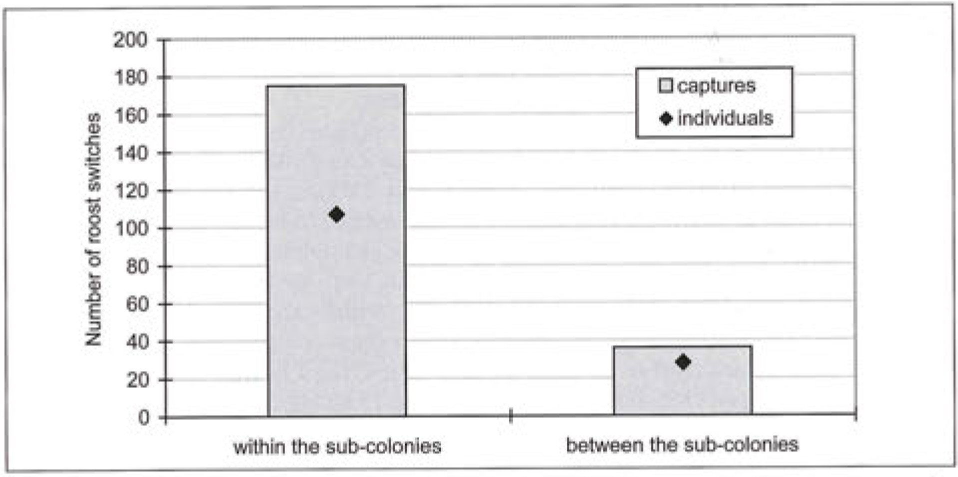

Figure 119: Quantity of roost switching within and between the two sub-colonies of the common pipistrelle in Wittelsberg during 1997–2000.

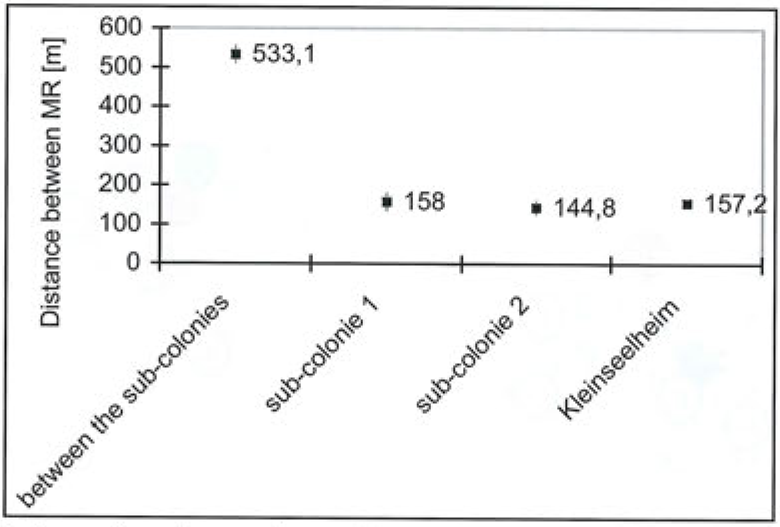

Figure 120: Average distance between the maternity roosts (MR) of the common pipistrelle in Kleinseelheim and between the sub-colonies in Wittelsberg.

correspond with the average distance of the roosts within the sub-colonies in Wittelsberg (158 m and 144.8 m). Ignoring the classification into sub-colonies in Wittelsberg, the average distance there between the roosts is with its 330 m much higher than in Kleinseelheim. This leads to the assumption that in Wittelsberg there exists not one large closed colony of the common pipistrelle, but two separate sub-colonies.

The roost switching behaviour of the common pipistrelle was also analysed in a third location of the study area, a slightly larger village called Gönnern (area: 0.7632 km², 515 buildings). During the years 1997–2000 a total 487 common pipistrelles were captured and 276 individuals banded. The recaptures of 126 individuals and the radio-tracking of 8 bats enabled the regular roost switching behaviour to be studied intensively (see also chapter 7.2.1 and FEYERABEND & SIMON 2000). The location of the 20 discovered roosts, the average distance of 522.3 m between them and the distribution of the bats recaptured in different roosts, all point to the existence of two sub-colonies at this location.

In order to find the spatial delimitation of a common pipistrell maternity roost assemblage in principle, nursery colonies and maternity roosts of adjoining villages were examined. Even villages or roosts within a distance of 1,000 m and 2,000 m showed only very limited exchange of individuals. Roost switching behaviour seemed to be very rare in distances of more than 2,000 m and such should be interpreted more as a summer change of village, which has to be distinguished from the roost switching behaviour (see table 27, compare chapter 7.4.1). Between the villages Kernbach (about 97 adult females) and Elmshausen (about 118 adult females), a considerable high exchange of 7 individuals could be observed in two roosts which are 1,700 m apart, whereby there occured no exchange of individuals between two locations 2,000 m apart (Kernbach and Caldern, about 133 adult females).

Several trapping operations took place at the different maternity roosts in the adjoining villages of Niedereisenhausen and Obereisenhausen (minimum distance between the roosts 1,200 m), so that many recaptures were possible, but almost exclusively within the specific village (see figure 121). Only two individuals changed from one location to the other.

Table 27: Numbers of common pipistrelles switching between two locations in conjunction to the minimum distances between the maternity roosts.

Distance [m]	Number of switching bats	Villages	Number of banded adult females of both villlages
1,200	2	Obereisenhausen-Niedereisenhausen	81 - 84
1,500	2	Lischeid - Josbach	66 - 12
1,700	7	Elmshausen - Kernbach	202 - 17
2,000	0	Kernbach - Caldern	17 - 264
2,000	0	Gönnern - Frechenhausen	230 - 67
2,400	1	Cappel - Marburg	116 - 127

To summarise, it can be said that the maternity roost assemblage of the common pipistrelle in regard to its spatial delimitation is limited to one location and reaches its limits at larger villages (more than 530 buildings, distances between the roosts more than about 500 m) whereby the formation of sub-colonies is already possible here. With increasing distances between the roosts (more than about 1,000 m), it is evident that independent colonies form. An exchange of individuals between the different colonies (distances up to about 1,700 m) is possible. At this point at the latest, the roost switching behaviour has its spatial limitation. All spatial relations between the maternity roosts within larger distances are judged to be summer changes of village of single common pipistrelle bats (see chapter 7.4.1).

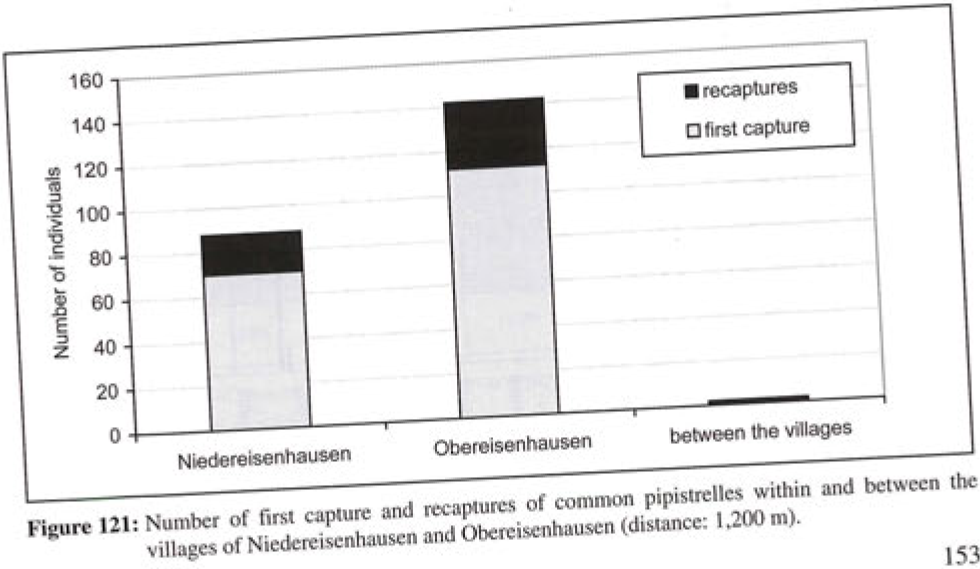

Figure 121: Number of first capture and recaptures of common pipistrelles within and between the villages of Niedereisenhausen and Obereisenhausen (distance: 1,200 m).

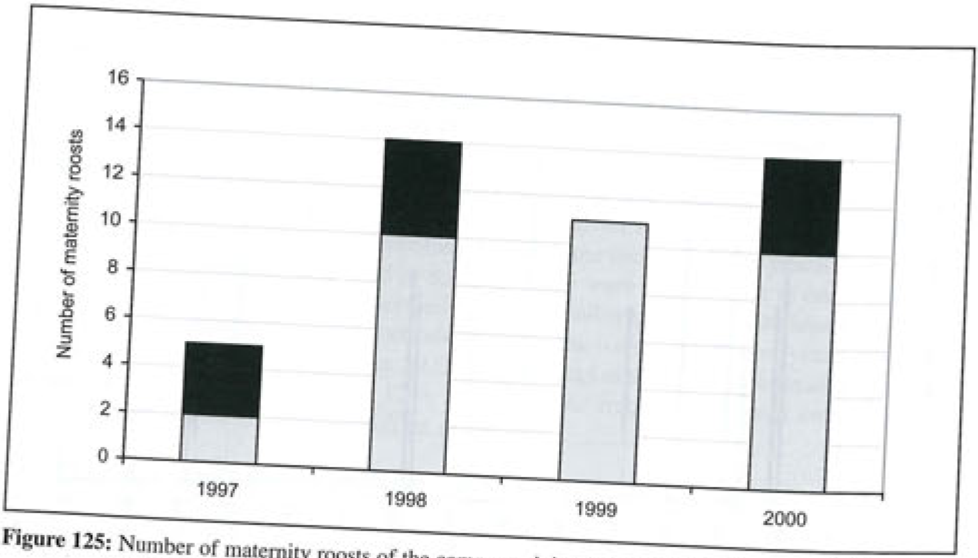

Figure 125: Number of maternity roosts of the common pipistrelle in Wittelsberg, used only in one year (black) or at least in two years (grey hatching).

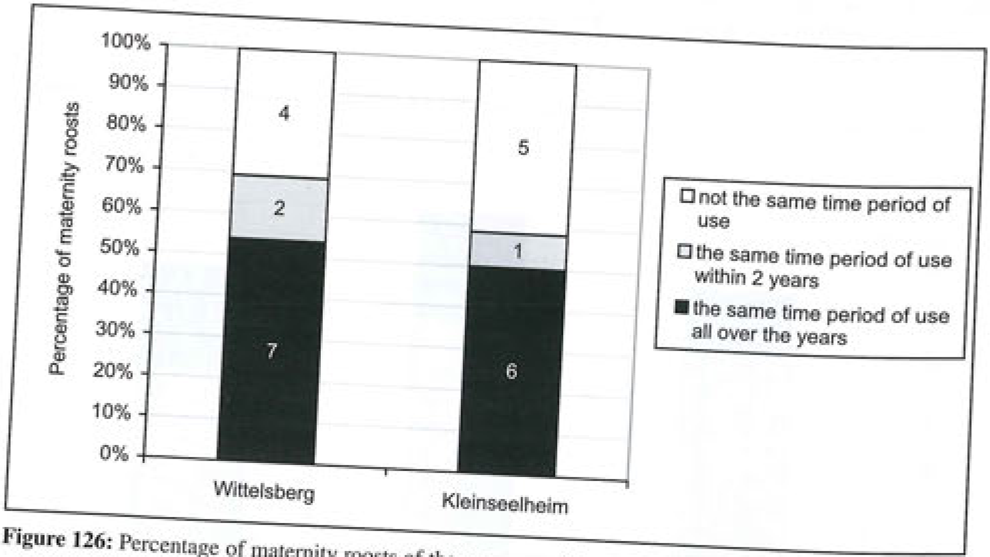

Figure 126: Percentage of maternity roosts of the common pipistrelle in Kleinseelheim and Wittelsberg, used at least for two years with the same or not the same period of use. The figures in the columns show the total number of the maternity roosts in question.

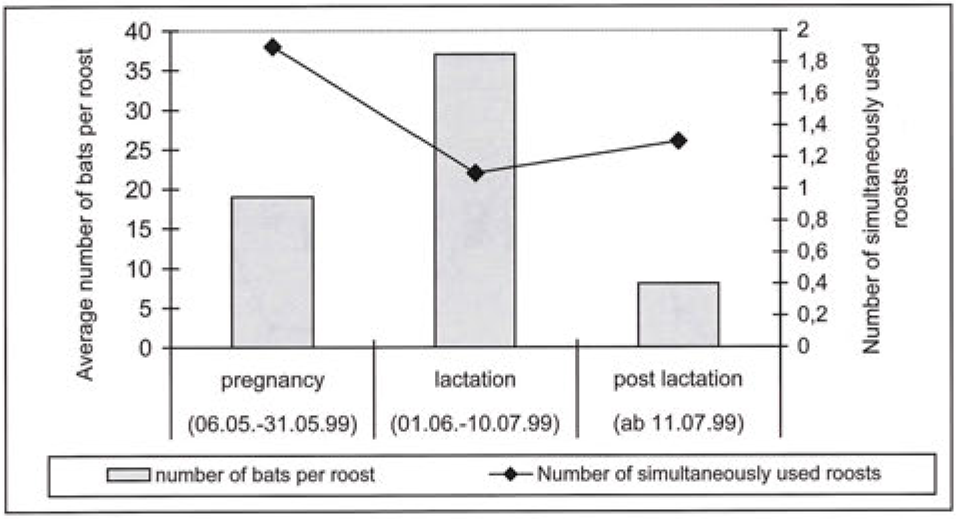

Figure 127: Number of simultaneously used roosts and number of bats per roost during pregnancy, lactation and post-lactation in the nursery colony of the common pipistrelle in Kleinseelheim.

7.2.1.3 The chronological process of roost switching

The following is intended to show the chronological process of roost switching in the common pipistrelle nursery colony in Kleinseelheim (see figure 128). During the lactation period, the common pipistrelles leave the roost within 30 minutes in nights without roost switching ("emergence peak") and they show regular activities (emergences, entries and approaches) during the night at their roost (see figure 128, June 19, 1999). On the night selected for this example, 30 bats entered their roost again during the last half-hour interval after sunset ("entry peak"); the number of exits corresponds with the number of entries.

On a night with roost switching, the emergences occur during two half-hour intervals after sunset (see figure 128, June 21, 1999). During the selected night, a relatively high activity could be observed, even though only 14 bats were in the roost (in contrast to the 38 bats two days before). The number of bat emergences was higher than the number of entries. Finally, all animals left the roost. The verification of this result clearly occurred on the following night (first night after the roost switch). There were no more bat emergences at sunset, but bats entered later in the night and exited very soon after. During the last half-hour intervals before sunrise, there was no activity at all at the roost (see figure 128, June 22, 1999).

7.2.1.4 Frequency of roost switching by adult, subadult and juvenile bats in one year

Roost switching behaviour could be proved by inspecting the individual ring number of sub-adult, adult and juvenile common pipistrelle bats. As soon as the juveniles become newly volant, the maternity roost assemblage dissolves. Therefore there is only a very short period of several days for the inquiry into the roost switching behaviour of juvenile bats, and a systematical study of the behaviour of the juveniles was not possible. The adults also switched roosts with their *non-volant* juveniles. Newly volant juveniles were recaptured in different roosts. This shows that juveniles already get to know different roosts during their first weeks of life.

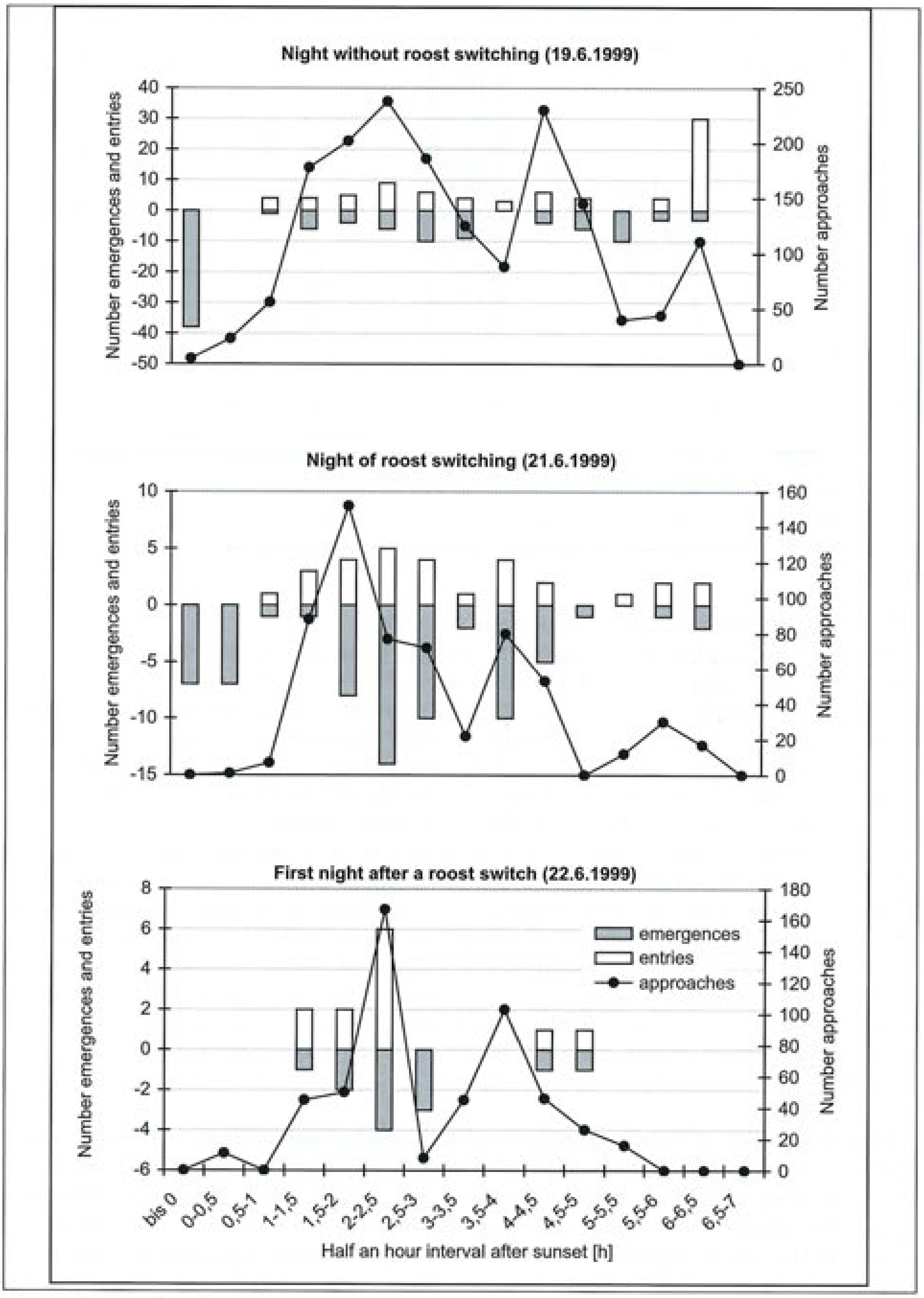

Figure 128: Number of entering, emerging and approaching bats within half-hour intervals at a common pipistrelle maternity roost in Kleinseelheim (at a night without roost switching, at a night of roost switching and the first night after a roost switch).

Adults and sub-adults were captured likewise from the end of April until the end of the maternity roost period. Both groups often switched roosts. The recapture rate of sub-adult bats within one year (60.6 %) was distinctly higher than that of adult bats (43.6 %). The percentage of sub-adults recaptured two or three times was always higher than the percentage of adults (see figure 129). Since the conditions of capture and roosts were identical for both groups, one may conclude that sub-adults are easier to capture than adults because of their lesser "life experience". More probable, however, is another ecological-ethological explanation: sub-adult females that more or less do not take part in reproduction have more time to inspect "new" roosts and they know less roosts, so that they can be found more frequently in different roosts. They are mostly not bound to an offspring with its needs and for their own security have to get to know as many new roosts as possible.

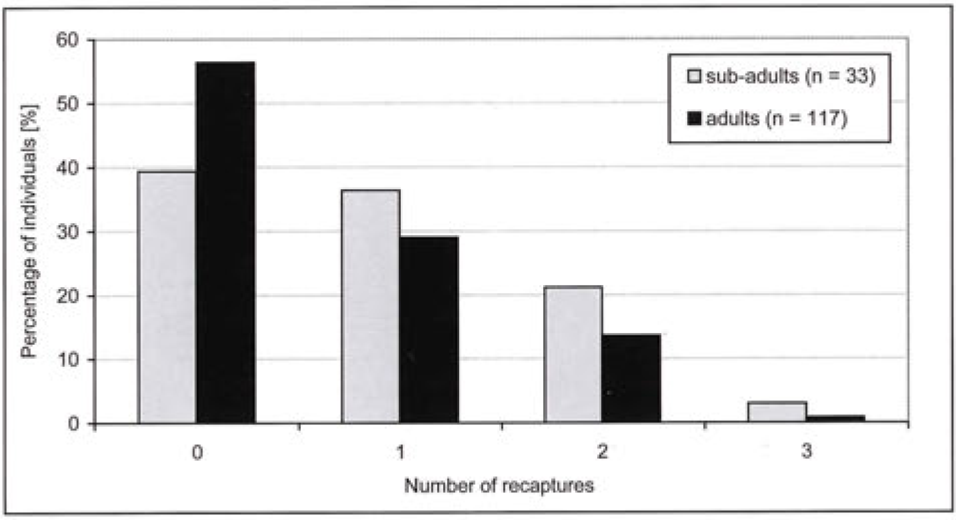

Figure 129: Percentage of adult and sub-adult individuals of the common pipistrelle not recaptured, recaptured once, twice or three times in one year.

7.2.2 Serotine bat

CATTO et al. (1996) proved roost switching in southern England for five of 13 radio-tracked females. The serotine bats switched temporarily between two roosts and sometimes several times. The only two non-reproducing females switched to a roost which was at a distance of 5 km and 10 km, respectively. HORÁČEK (1981) investigated the general seasonal activity at a maternity roost of the serotine bat in the Czech Republic. During the three years of research, the first animals moved into the roost from the middle of May onwards, respectively. As the serotine bats had left the roost up to three times during the maternity roost period, the author deduced the use of other roosts. NATUSCHKE (1960) reported spontaneous switches of serotine bats, especially before the birth of the young, to another place within the roost. WAGNER (1987) mentioned alternative serotine bat roosts to the maternity roosts, but did not explain the correlation more explicitly.

In the Netherlands, GLAS (1981) could not observe any roost switch in the serotine bat maternity colony. The number of bats increased there until the end of May, and the first bats left the roost again from the beginning of August onwards.

7.2.2.1 Spatial examination of the roost assemblage

In the village Großseelheim, a serotine bat colony used at least 10 different roosts between June 29th and August 9th 1999 (see figure 130). Up to 39 emerging serotine bats were counted. The ring numbers proved a roost switch by 7 individuals. Since on the one hand serotine bats are difficult to capture due to their noise sensitivity and on the other hand their roosts are barely accessible due to their height, relatively few captures took place at serotine bat roosts.

The maternity roosts of one serotine bat colony were relatively close to each other. Thus, the mean distance between the maternity roosts in Großseelheim was 110 m and in the slightly bigger town Kirchhain 260 m (see figure 131).

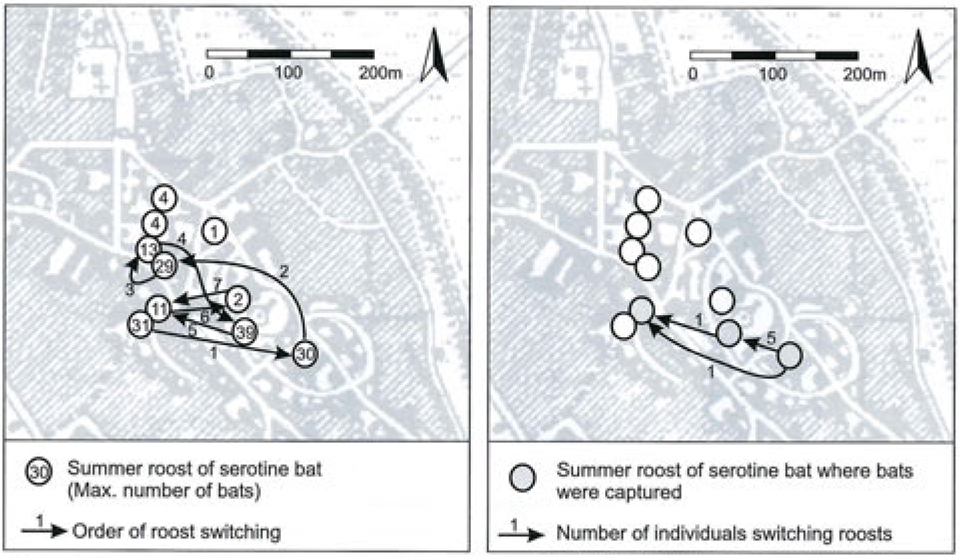

Figure 130: Roost switching of the serotine bat in Großseelheim between June 29th and August 9th 1999; on the left: proved through counts of emergences, on the right: proved through capture and recapture at three maternity roosts.

Roost switching of the serotine bat at a building complex

Between 18th April and 15th July 1999, roost switching of the serotine bat at a big building was investigated on three sides of the building (compare chapter 3.1.6). The animals used gaps above the windows as roosts. A total 55 of the 123 window gaps on the western, southern, and eastern sides of the building were used as summer roosts by serotine bats in 1999. Thirty-one of these roosts were maternity roosts and 24 were single roosts. It is worth pointing out that 15 of the maternity roosts were also used once or even more often as day roosts by single animals. The frequency of use of the single crevices lay between one and six times for 25 counts (see figure 132). The number of animals occupying crevices here, lay between one and 37.

Some differences concerning the use of the three sides of the building were found (compare chapter 5.3). While single animals preferred to use the crevice roosts on the eastern side (54 %), the maternity roost colony especially favoured the windows of the southern (45.2 %)

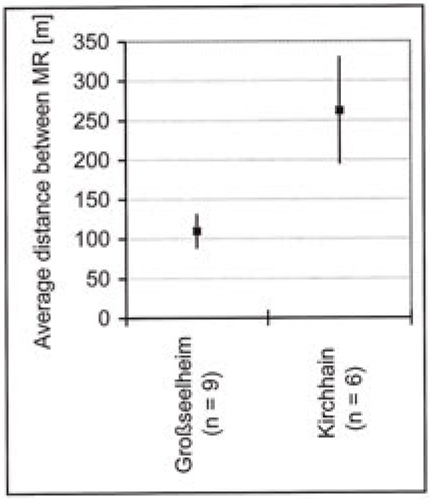

Figure 131:
Mean distances between the maternity roosts (MR) of each serotine bat colony in Großseelhaim and Kirchhain, including a 95 % – confidence interval (n= number of MR).

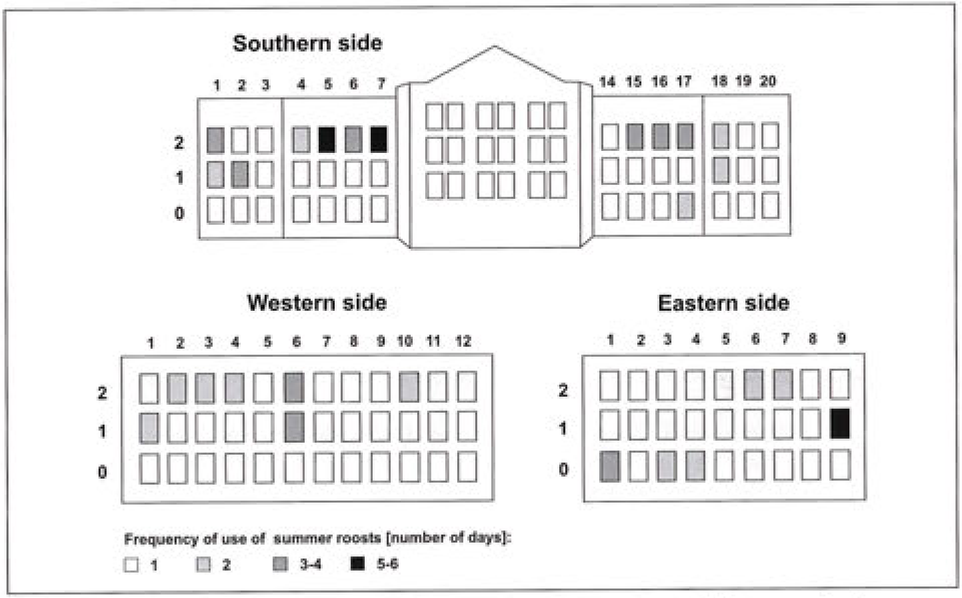

Figure 132: Frequency of use of summer roosts by serotine bats at a large building complex (roost complex "Psychology Building") in the Marburg town centre (25 emergence counts between April 18th and July 15th 1999).

and western sides (41.9 %). Judging by the counts of emergences (22 counts during the period between May 20th and July 15th 1999), there was a very high rate of roost switching between the window crevice roosts used as day roosts by the colony. Thus, the number of summer roost switchings of the colony was at least 15 (see figure 133).

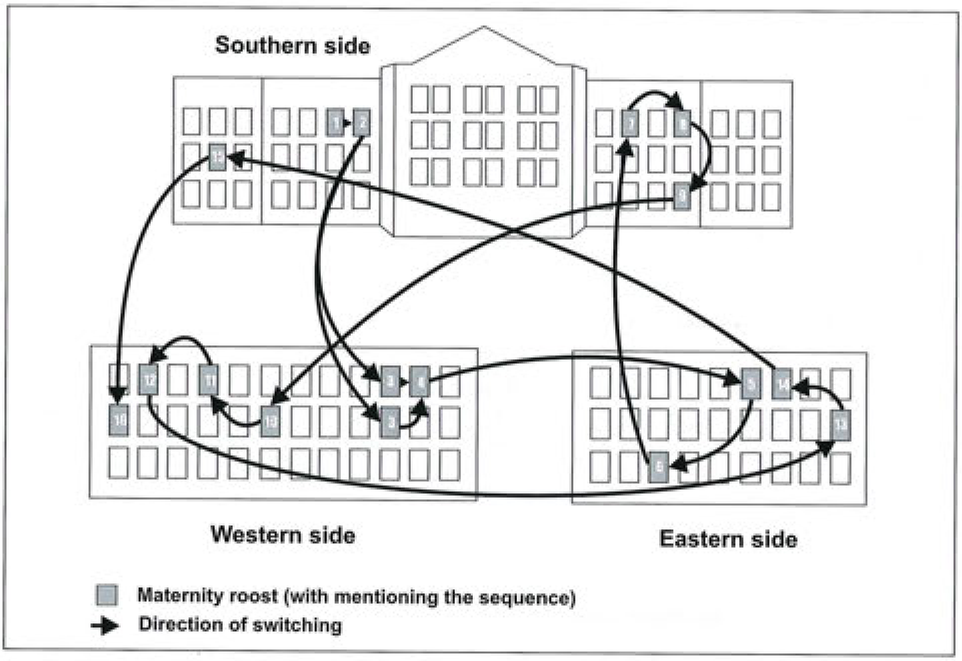

Figure 133: Roost switching behaviour of the Marburg serotine bat colony from May 20th and July 15th 1999 in the roost assemblage inhabiting a large building complex in Marburg.

Nocturnal activity at the roost

The nocturnal activity patterns at the "Psychology Building" roost complex in Marburg could be determined by means of observations over whole nights. There were different levels of activity in a single night. After the first hunting phase, which lasted between one and three hours, the animals usually entered a crevice roost at the building again after circling in front of it, or after approaching it several times.

In figure 134 it becomes evident that, in one night of roost switching, the originally occupied roost (grey) was approached again by the bats in the course of the night. The existence of further roosts, not formerly known, was demonstrated by the fact that other serotine bats from outside the roost complex joined in; they occupied an additional three new roosts (the sum of all entries was clearly higher than that of all emergences). Figure 135 represents an example of an incomplete roost switch on another night: the animals which emerged at evening from a single crevice roost, divided themselves over three roosts when flying in next morning. In the hour before dawn in both nights there was a frequent entering and emerging by the animals at the crevice roosts. This behaviour could be observed regularly at further serotine bat roosts.

Spatial delimitation of the roost assemblage

Regular captures at serotine bat roosts were carried out in five villages in the project area which are relatively close to each other. In all villages the bats used several roosts. Recaptures were always within the same village of first capture. A switch between the roosts of different villages was not ascertained. Also in other colonies of the project area, no serotine bats from other villages were captured (with a total of more than 600 captures of serotine bats within the project area). Apparently the colonies are limited to certain villages and a roost

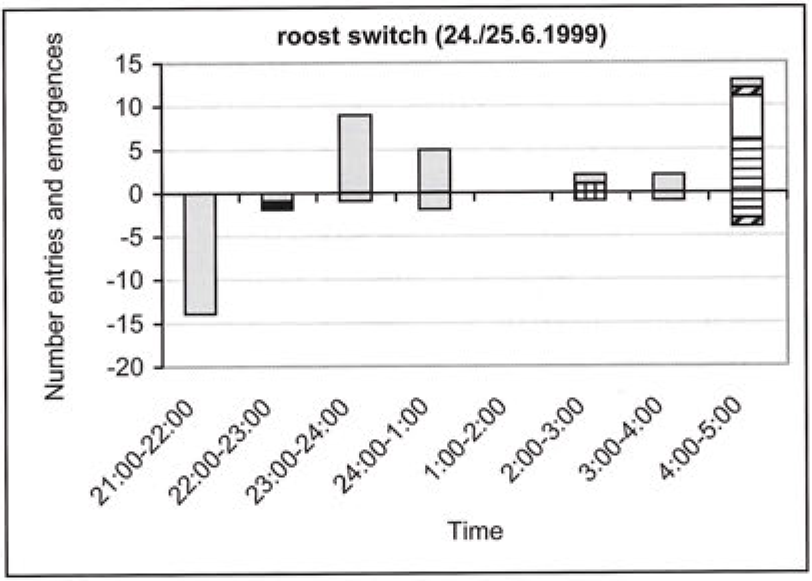

Figure 134: Nocturnal activity of the serotine bat at the roost assemblage at the Psychology Building in Marburg. The different hatchings band the different crevice roosts. The bats emerging from one roost (grey) enter again at night by 1 a.m. Between 4 a.m. and 5 a.m. further bats enter three other roosts.

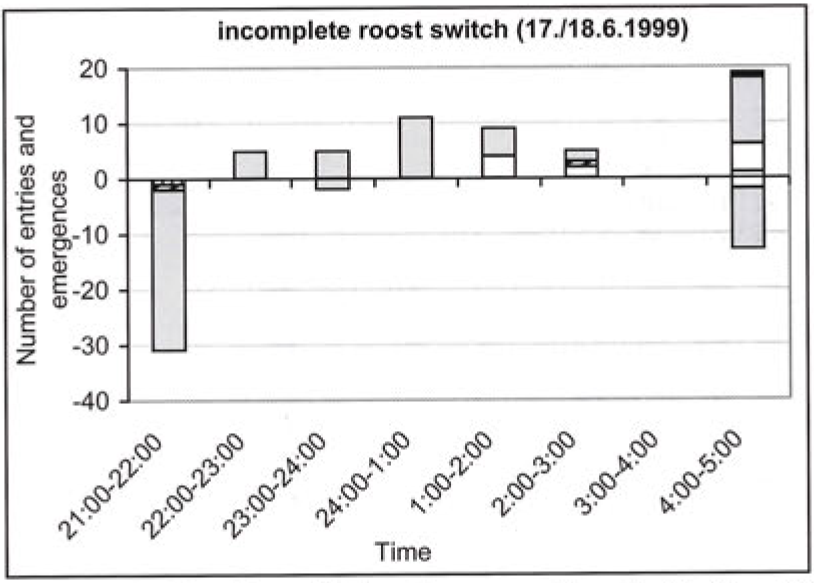

Figure 135: Nocturnal activity of the serotine bat at the roost assemblage at the Psychology Building in Marburg. The different hatchings band the different roost gaps. The bats emerging from one roost (grey) partly return to their original roost towards morning and switch to two other roosts.

switch between different colonies is so rare that it could not be observed. In contrast, moves to single or mating roosts beyond the maternity roost village could be registered time and again (compare chapter 7.4.2).

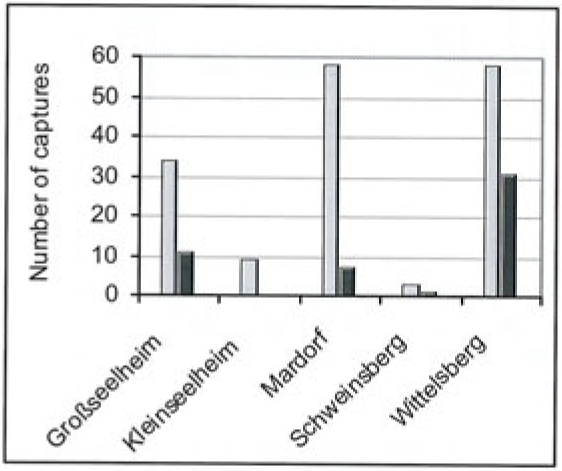

Figure 136: Number of banded individuals in neighbouring villages with serotine bat maternity colonies (grey) and recaptures within the respective villages (black). No exchange of individuals could be proved between villages.

7.2.2.2 Temporal examination of roost switching

In Kirchhain the serotine bats used up to six different maternity roosts in one year (see figure 137), occupying up to four roosts at the same time. The size of the maternity colony was up to 60 adult females (see figure 137). The real number of occupied maternity roosts is

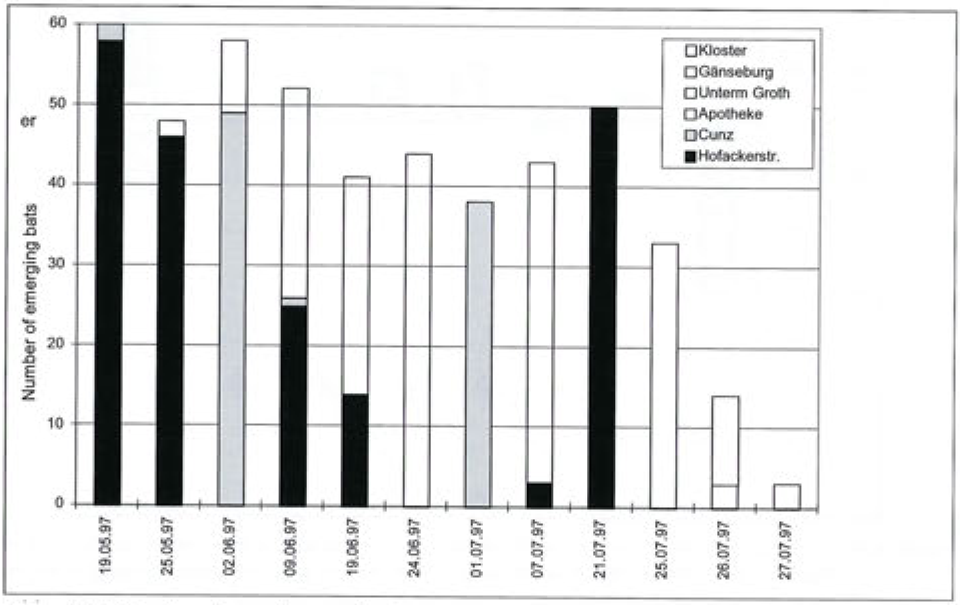

Figure 137: Number of emerging serotine bats at a maternity roost in Kirchhain in 1997.

apparently higher, as rarely all animals were recorded in simultaneous counts at all known roosts.

The serotine bats occupied any one roost on two to 26 successive days. Within one colony, they switched their roost on average every six days (Kirchhain and Großseelheim). At the building complex in Marburg they visited another roost every three days on average. The maternity roosts in the villages were used several times during a maternity period. Thus, so-called main roosts which were occupied up to seven times within one season, can be distinguished from secondary roosts which were used once or twice during a maternity period. Furthermore the temporal order of roost occupation was similar over several years (see figures 137 and 138). The roost labelled "pharmacy" which was used several times in 1997 was destroyed in 1998. A replacement roost was created at the same building, which, however, was not accepted by the serotine bats.

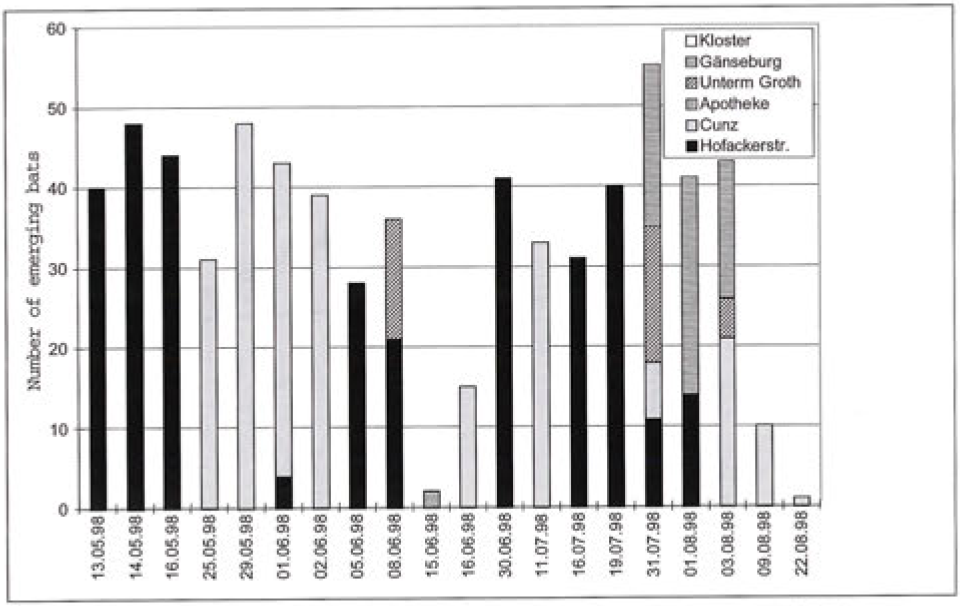

Figure 138: Number of emerging serotine bats at six maternity roosts in Kirchhain in 1998 (there were no counts at the roost labelled "convent", but the ultrasound sensors registered some activity at the beginning of August).

7.2.3 Greater mouse-eared bat

In contrast to species like the common pipistrelle or (in part) the serotine bat, greater mouse-eared bats occupy each roost very conservatively over many years and rarely switch their maternity roosts completely. Direct investigations on roost switches by the greater mouse-eared bat are mostly lacking. Only ROER (1988) and NATUSCHKE (1960) could prove sufficiently in their investigations that regular roost switches can be observed for this bat species as well. In some further, less systematical studies, single switches were proved repeatedly. HUMMITZSCHE (1960) could prove a roost switch of about 1,000 ringed animals of a colony in Leipzig and further colonies in the surroundings to another maternity roost 27 km away (after two years). Once, a roost switch of 12 individuals of a neighbouring colony could be proven.

There are three maternity roosts of the greater mouse-eared bat in the project area (see table 28), as well as a further one just outside the border of the project area. A regular change of hanging places, dependent on the temperature, could be determined within the attic-roosts of the greater mouse-eared bat (see chapter 5.10.5). Nonetheless, the exchange of individuals between maternity colonies, taking place regularly and at wide ranges within the project area, is far more spectacular (see figure 139). Large distances of up to 16 km were covered here

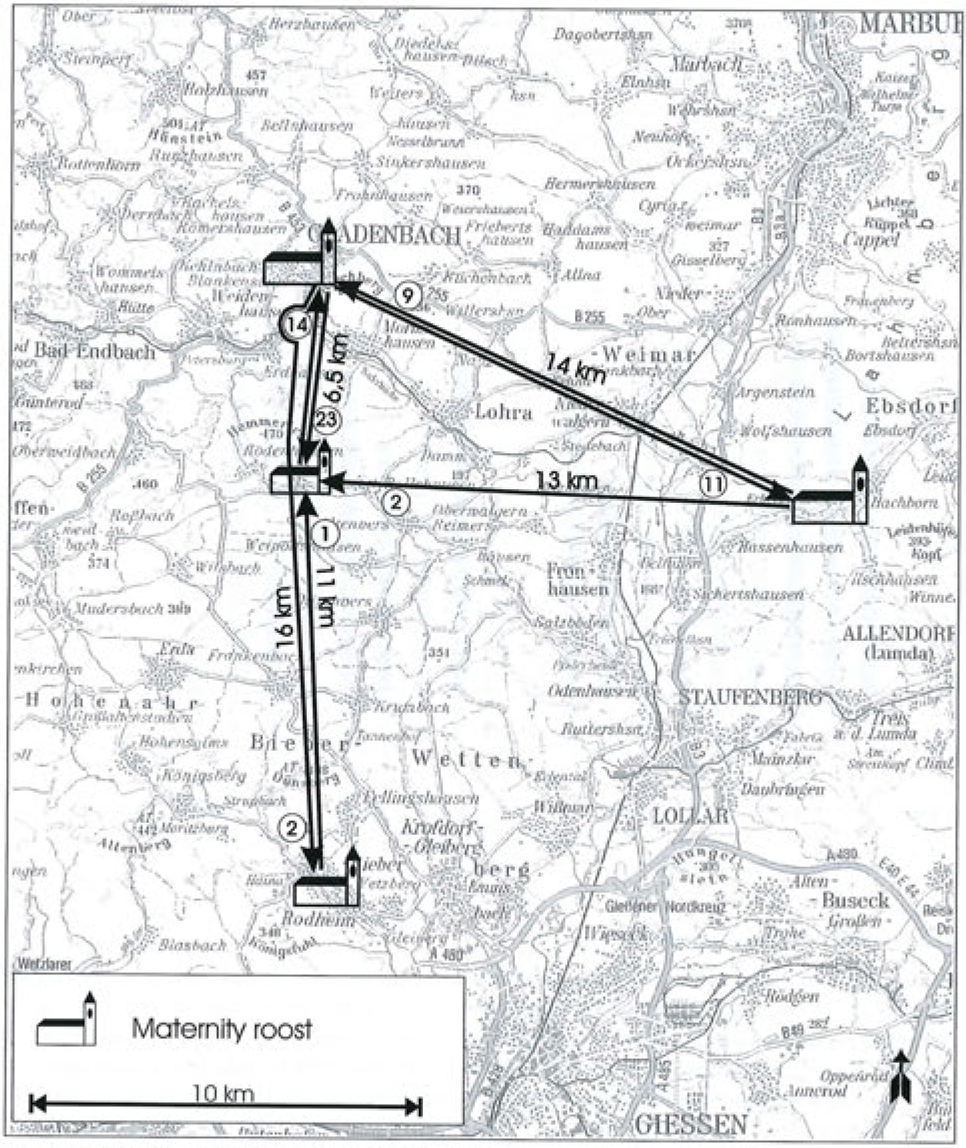

Figure 139: Overview of switching incidents (n = 62) between maternity roosts of the greater mouse-eared bat in the years 1998–2000. The numbers in circles represent the number of switches. The number of individuals involved is 37.

time and again. During the period 1998 to 2000 there was a total 62 switches by 37 individuals. In contrast to the common pipistrelle and serotine bat this is not a roost switch within a colony (roost assemblage), but the regular summer change of location between different colonies ("colony assemblage").

The bats moving to another colony can be regarded from two points of view: on the one hand from the perspective of the colony from which the bat departs (potential emigrants) and on the other hand from the perspective of the colony where the ‚strangers' arrive (potential immigrants). Thus, the potential emigrants and immigrants in a maternity colony can be determined as a percentage. The smallest colony in Seelbach (30 individuals) has by far the greatest percentage of emigrants and immigrants. Nine emigrants (30 %) and 12 immigrants (27.5 %) in Seelbach can be compared to the 25 emigrants (8.3 %) and 13 immigrants (4.3 %) of the biggest colony in Gladenbach (300 individuals).

Table 28 shows the percentages of potential emigrants and immigrants per year and colony. The data show that the percentage of switching females is considerably higher in smaller colonies like Erbenhausen and Seelbach than in the biggest colony in Gladenbach. There are approximately 3–11 % greater mouse-eared batfemales (a trend of 8–11 % for big spot checks) in the maternity colony in Gladenbach, which are in contact with other maternity roosts in the surroundings. In Erbenhausen the percentage of switching animals is about 12 %–15 % and therefore despite the low density of investigation in Erbenhausen, clearly higher than in Gladenbach. However, the most striking fact is the extremely high percentage of switching females in Seelbach: here, the percentage lies between 23 % and 66 % per year. A quota of about 60 % was obtained through intense spot checks. The high percentage of switching animals could be pointing to the fact that the smaller colony in Seelbach, which was detected at the beginning of the 1990s, is still in the phase of establishment.

Table 28: Captures of all females switching roost during all years of investigations, in the maternity colonies of the greater mouse-eared bat. Each individual is taken into account once a year, but otherwise can be counted several times. The last column represents the calculated percentage of switching individuals, proceeding from the total annual captures.

			Switching bats	
Colony village	**Year**	**Adult females [Ind.]**	**[Ind.]**	**[%]**
Erbenhausen	1997	7	1	14.3
	1998			
	1999	85	13	15.3
	2000	24	3	12.5
Gladenbach	1997	38	3	7.9
	1998	225	24	10.7
	1999	150	4	2.7
	2000	273	24	8.8
Seelbach	1997	13	3	23.1
	1998	6	4	66.7
	1999	26	13	50.0
	2000	30	19	63.3

Eleven of 14 radio-tracked bats from Gladenbach and Seelbach used at least one additional day roost, apart from the attic. Four of those 19 day roosts were located in buildings and the remainder were tree roosts. The day roosts of the greater mouse-eared bat lay in a distance of 2.9 km to 12.8 km from the maternity roost. All day roosts lay in or close to hunting grounds (compare chapter 7.3.3). There were almost exclusively single animals in the day roosts. One tree hollow accommodated five greater mouse-eared bats during the maternity period.

7.2.4 Whiskered bat

There is little information in the literature about the roost switching behaviour of the whiskered bat. FRANKE (1997) described this species as faithful to their location and observed roost switching between two batboxes. NATUSCHKE (1960) reported roost switching in an almost completely self-contained colony. The bats switched between several roosts behind the shutters of the same building or to those of a neighbouring building 850 m away.

By means of telemetry a repeated roost switch by an adult female between a slate-facade roost at a building and a roost in the forest (hunter's lookout tower) was observed. The distance between these roosts was 1,250 m.

In addition, by means of emergence counts at maternity roosts of the whiskered bat, the use of several roosts per season could be indirectly proved. Thus, at the beginning of June, for example, 86 animals could be observed emerging at one maternity roost, the next day 91, and three weeks later none at all. The number of adult females per roost lay between 69 and 112 animals in the different villages.

7.2.5 Natterer's bat

BÖHME & NATUSCHKE (1967) described the Natterer's bat as a species which is very faithful to its roost, using the same roost (a hollow space behind a roof beam panelling) even after reconstruction works to their building. CERVENÝ & HORÁČEK (1981) observed roost switches as well as changes of position within a roost by this species. In the forest, regular and frequent roost switches between nest boxes were recorded (on average every one to four days) (LABES & KÖHLER 1987, LAUFENS 1973). SIEMERS et al. (1999) recorded 12 roost switches of one colony in the forest within 11 weeks between nest boxes and a branch hollow. The roost switching of the Natterer's bat was not methodically investigated within the project's framework and can therefore only be regarded as anecdotal. The investigation of a Natterer's bat maternity colony in the ceiling of a cowshed within the project's framework, led to the conclusion that the animals switched repeatedly between two roosts within one cowshed (hollow space in the breezeblock ceiling) and were continously present there from the end of April to the end of July. On 30th June 1999, all animals left the roost and did not return that year. The roost was used over several successive years (1999 to 2001) and was known before as well. Other maternity roosts of the Natterer's bat that were discovered in the course of the investigations were all occupied sporadically – none of them more than several weeks. This is also the case for one more roost in a different cowshed.

7.2.6 Barbastelle bat

By means of telemetrical investigations of the barbastelle bat in the forest, STEINHAUSER (2002) determined an almost daily switch of roosts (especially behind bark sticking out on trees) and also a daily change of the composition of the group in each roost (two to 12 adult animals). The roosts were situated in an area of 800 m x 800 m. NATUSCHKE (1960) observed roost switching by maternity colonies behind window shutters. However, sometimes just the hanging places within a roost were changed.

In the year 2000 it was possible to demonstrate, by means of emergence counts at a maternity roost of the barbastelle bat, that the animals stayed almost exclusively on one building. The barbastelle bat used at least 13 different places behind the building's slate facade (see figure 140) between 17th April and 23rd August 2000. The colony consisted of 39 adult females (emergence count); when the young were newly volant, a maximum 67 bats were counted (see table 29). While the barbastelle bats switched crevice roosts at the buildings constantly until the end of May, in June the bats stayed almost exclusively in one place behind the slate facade. A maximum of four different crevice roosts were occupied simultaneously. At the beginning of August all animals left the roost building for two weeks, and their whereabouts were unknown. The building (an old manor-house) has apparently been serving as maternity roost for the barbastelle bat for a long time and has been used by the animals every year since its discovery in 1998. In 1999, the temporary use was recorded of a further building in close proximity to the known roost building. By means of telemetrical investigations it was shown that one female switched to a tree roost from a roost in the building, the next day into another tree roost, and the following day it returned to the original building. Both tree roosts were located in one of the bat's hunting grounds. The maximum distance between the three roosts was 2,250 m.

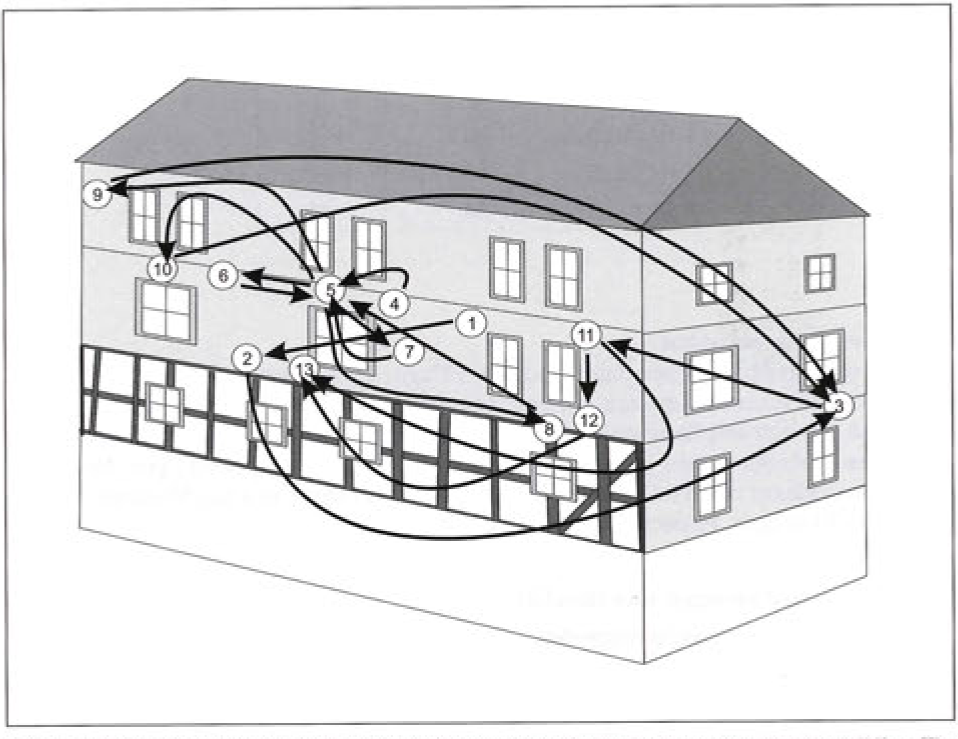

Figure 140: Roost switch of the Barbastelle bat between 17th April and 23rd August 2000 at a building. The roosts (1–13) are situated behind a slate panelling.

Table 29: Number of emerging barbastelle bats at a building in 2000. The crevice roosts are situated behind different parts of the slate panelling (roost 1–13). ? = unknown, * = roost is situated on the gable side, all remaining roosts are situated at the back, compare figure 140.

Date	Number of bats	Roost
17.04.00	13	backside
26.04.00	17	1
03.05.00	39	2
08.05.00	?	3*
23.05.00	38	4
29.05.00	39	5
05.06.00	39	5
17.06.00	38	5
21.06.00	27	5;6;7;8
28.06.00	36	5
03.07.00	38	9;10
12.07.00	37	3*
19.07.00	39	11
25.07.00	67	11
26.07.00	63	11
02.08.00	0	?
06.08.00	0	?
13.08.00	49	11;12
16.08.00	43	11;12
23.08.00	38	13

7.2.7 Grey long-eared bat

Grey long-eared bats are very faithful to their villages (FUHRMANN, 1994, HIEBSCH 1983). Switches were recorded between different hanging places in the roost (KIEFER & VEITH 1998) and between neighbouring roosts (GAISLER & HANÁK 1969, HIEBSCH 1983).

By means of telemetrical investigations within the projects framework, grey long-eared bats in two villages could be observed to switch between roosts in a neighbouring building (10 m and 50 m apart, respectively).

7.3 Utilisation of foraging sites (level 2)

One possible reason for a specific choice of roost can be its proximity to foraging sites (see KUNZ 1982). EICHSTÄDT & BASSUS (1995) demonstrated that common pipistrelles changed their roost to be up to 2 km closer to their foraging site. The roost location chosen by common long-eared bats was shown to be related to the proximity of their foraging sites (ENTWISTLE et al. 1997).

7.3.1 Common pipistrelle

Most literature mentions riparian vegetation and inshore waters as foraging sites for the common pipistrelle (DE JONG & AHLÉN 1991, EICHSTÄDT & BASSUS 1995, JANSEN 1993, OAKELEY & JONES 1998, RACEY & SWIFT 1985, RYDELL et al. 1994, SPEAKMAN et al. 1991, SPEAKMAN et al. 1995, STUTZ & HAFFNER 1985, TRAPPMANN 1996, VAUGHAN et al. 1997, WALSH & HARRIS 1996a, WALSH & HARRIS 1996b). Additionally, the common pipistrelle hunts on the edges of forests, in deciduous forests, mixed deciduous/coniferous woodland, in hedges and orchards and also over open country, pastures and fields (EICHSTÄDT & BASSUS 1995, DE JONG & AHLÉN 1991, DE JONG 1995, JANSEN 1993, GODMANN 1996, TRAPPMANN 1996).

In investigations in Scotland the common pipistrelle (no distinction made between 45 kHz and 55 kHz calling type) had a distance between roost and foraging sites of maximum 2.5 km and 5.1 km during breeding season and maximum 2.5 km and 3.7 km during the lactation period. The average distance lay between 1.0 km and 1.8 km before lactation and 1.0 km to 1.3 km during lactation (RACEY & SWIFT 1985). A further investigation in Scotland observing animals hunting on rivers showed the foraging site could be anywhere between 1 km and 50 m from the roost (SPEAKMAN et al. 1995). In Kassel (Hesse), JANSEN (1993) measured distances between roost and foraging sites of under 2 km. EICHSTÄDT & BASSUS (1995) found the shortest distances, namely 50 to 300 m.

The average distance between current maternity roost and foraging sites were ascertained in this study via radio telemetry. A total of 8 common pipistrelles were radio-tracked over 24 nights between 14. 5. 97 and 1. 8. 97. Twenty-three different foraging sites could be distinguished. Twelve of these were forest clearings. Another five were on the forest edge or were forest paths. In addition, the common pipistrelle used vegetation along a stream and orchards. All foraging sites were in a maximum radius of 2 km from the maternity roost. The average distance between maternity roost and foraging sites was 840 m (see figure 141). The relationship between the existence of a maternity roost in a particular location to its distance from potential foraging sites will be discussed in chapter 11.2.1.

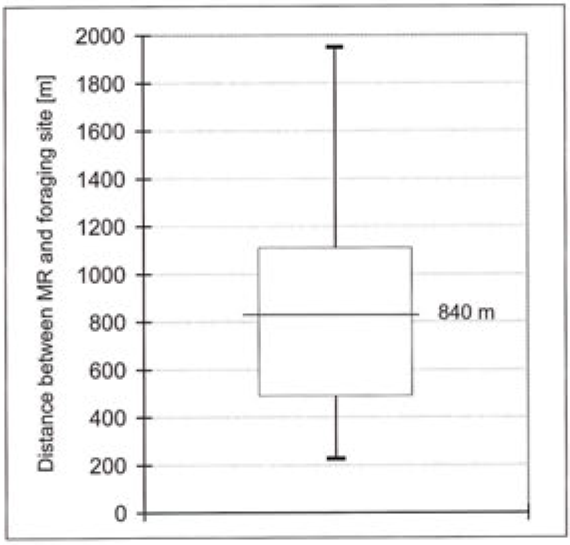

Figure 141: Average distance (with details on quartile, minimum und maximum) between current maternity roost of the common pipistrelle (MR) and its foraging sites in Gönnern, ascertained via telemetry (8 bats, 24 nights).

Nocturnal sojourn in roost

Common pipistrelles spend an average 12 % of the night (40.3 minutes) in their roost (see figure 142).

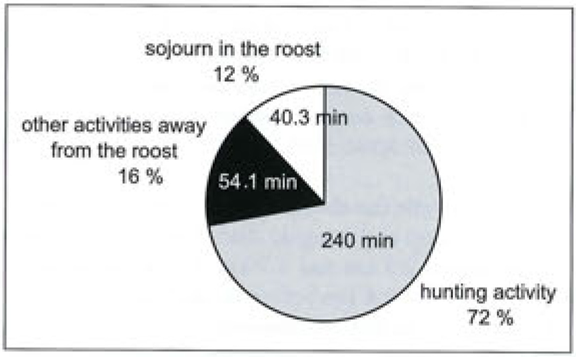

Figure 142: Average divisions of time spent by tracked common pipistrelles on hunting activities, other activities away from the roost (e. g. flights, swarming near the roost, non-hunting activities) and sojourn in the roost.

If one makes a distinction between the reproductive status of the tracked bats, the pregnant females spend the longest period in their roosts and have by far the shortest average period of activity (see table 30). The lactating females seem to need to make up for a greater energy requirement and spend the longest percentage of time in their foraging sites (77 %).

Table 30: Divisions of time on a percentage basis spent by tracked common pipistrelles on hunting activities, other activities away from the roost (e. g. flights, swarming near the roost, non-hunting activities) and sojourn in the roost, differentiated according to sex and reproductive status (all adult).

Reproductive status	Sex	Average period of activity [min]	Hunting activity [%]	Sojourn in roost [%]	Other activity [%]	Study period	Number of bats	Number of nights
Pregnant	w	283.6	61	20	19	14. 5.-26. 5. 97	2	7
Lactating	w	361	77	4	19	28. 7.-1. 8. 97	2	8
Not reproductive	w	420	74	13	13	16. 7.-19. 7. 97	2	4
	m	305	71	17	12	03. 6.-10. 6. 97	2	5

7.3.2 Serotine bat

The foraging sites of the serotine bat are to be found in the parks, orchards and gardens of populated areas (GLAS 1981, KLAWITTER 1986, WEIDNER 1995) and also on pastures, the edges of forests, in timber stands, tree-lined avenues and hedges (CATTO et al. 1996, DEGN 1983, LESINSKI et al. 2000). The distance between roost and foraging sites varies between a short 100 m and a maximum 11.5 km (CATTO et al. 1996, DEGN 1983, DIEHL 1994, HAVEKOST 1960, PEREZ & IBAÑEZ 1991, ROBINSON & STEBBINGS 1997, WEIDNER 1995).

Details on the size of the home range vary considerably. They have been stated as > 2 km² (DEGN 1983), 16 km² (DIEHL 1994), and 24–77 km² (core area 13–33 km²) (ROBINSON & STEBBINGS 1997) per maternity roost. The home range of individually radio-tracked animals varies between 1.61 km² and 17.05 km² (PEREZ & IBAÑEZ 1991) and 0.16 km² and 47.58 km² (ROBINSON & STEBBINGS 1997).

The 11 serotine bats tracked over 46 nights in 1998 for this project varied in their preference for a certain type of foraging site over the maternity period (see figure 143). In May they hunted predominantly on forest edges. In July the serotine bats used a total of 6 types of foraging site. In this month the animals were found hunting mainly over open country and in gardens and less in forests or on forest edges (see chapter 11.2.3). In August, open county, gardens and inshore waters were used in equal part. The serotine bat's intensive preference for grazed pasture (cattle, cows) is conspicuous. The presence of serotine bats in an area may be more easily ascertained by searching for them hunting in pasture in the evening.

The average distance between maternity roost and foraging sites of the serotine bat was 1,250 m (± 700 m [95 % confidence interval]). The maximum distance from roost to a foraging site was 5,700 m.

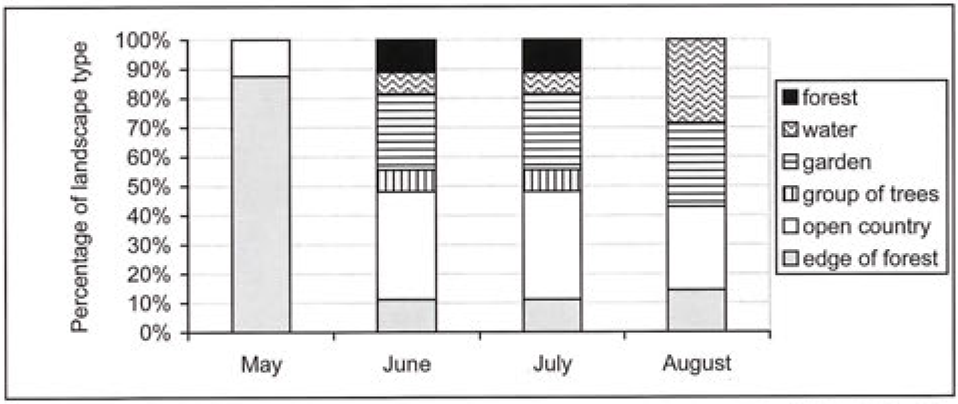

Figure 143: Percentage of landscape types of foraging sites used by serotine bats (11 individuals, 46 radio-tracking nights) between May and August.

7.3.3 Greater mouse-eared bat

According to the literature, the greater mouse-eared bat favours deciduous and mixed forests as foraging sites (EICHSTÄDT 1995, GÜTTINGER 1997, LIEGL & HELVERSEN 1987). Some authors also name as potential foraging sites coniferous forests (AUDET 1990, RUDOLPH & LIEGL 1990, ZAHN & KRÜGER-BARVELS 1996) and freshly mown/grazed or harvested agricultural land (ARLETTAZ 1996, GÜTTINGER 1997, JANSEN 1993). According to the literature, greater mouse-eared bats regularly cover distances of up to 10 km between their maternity roost and their foraging sites (ARLETTAZ 1996, AUDET 1990, GÜTTINGER 1997, LIEGL & HELVERSEN 1987), and in individual cases they will travel up to 17 km or 25 km (GÜTTINGER 1997, ARLETTAZ 1995).

Greater mouse-eared bats from two of the three known maternity roosts in the project area, 6.5 km apart, were investigated via radio telemetry. Seven animals from each colony were radio-tracked. The bats from the larger colony in Gladenbach with up to 300 adult females had a much larger homerange (155 km²) than those from the smaller colony in Seelbach with 30 adults (10 km²) (see figure 144). The two homeranges intersected in only one village 1 km² in size. Ninety-five percent of the foraging sites were in forests, 4 % in open country. If one

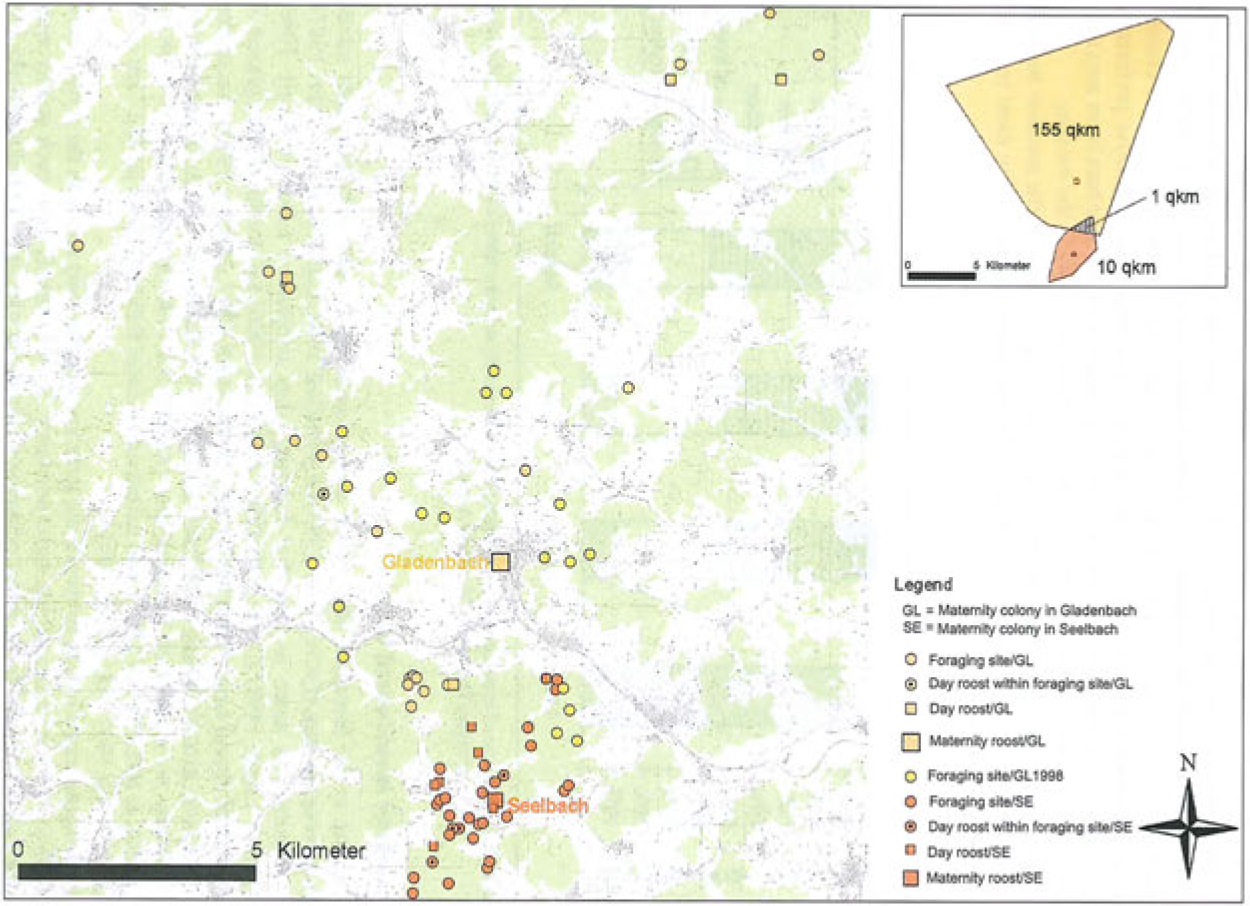

Figure 144: Position of foraging sites of the 14 tracked greater mouse-eared bats from the Gladenbach colony (300 individuals) and Seelbach colony (30 individuals) in the years 1998–2000.

compares the type of foraging sites chosen to the potentially available in a grid of 100 randomly selected reference areas in the total project area, the greater mouse-eared bat definitely favoured deciduous and mixed forests – coniferous forests were avoided. The tracked bats favoured forests with an average tree interval of 2 m to 4 m, with the lowest tree level being at least 20 m high and with a ground surface at least 75 % clear. The distance between maternity roost and foraging sites differed significantly between the two maternity colonies of the greater mouse-eared bat in the study: whereas the foraging sites of the smaller maternity colony (Seelbach) were up to a maximum 3 km away from the maternity roost, the foraging sites of the larger colony (Gladenbach, up to 300 animals) were up to 13.8 km to the north (see figure 144). The foraging sites in a southerly direction were a maximum 5 km away and did not intersect with the area of the Seelbach colony 6.5 km to the south. Eighty percent of the foraging sites were located within a 7.5 km radius of the maternity roost in Gladenbach. Apart from their maternity colony, the greater mouse-eared bat used a further 19 day roosts (15 in tree hollows, four in buildings), which, with two exceptions (with five animals) were individual roosts. All day roosts were situated in the foraging sites or close by to them.

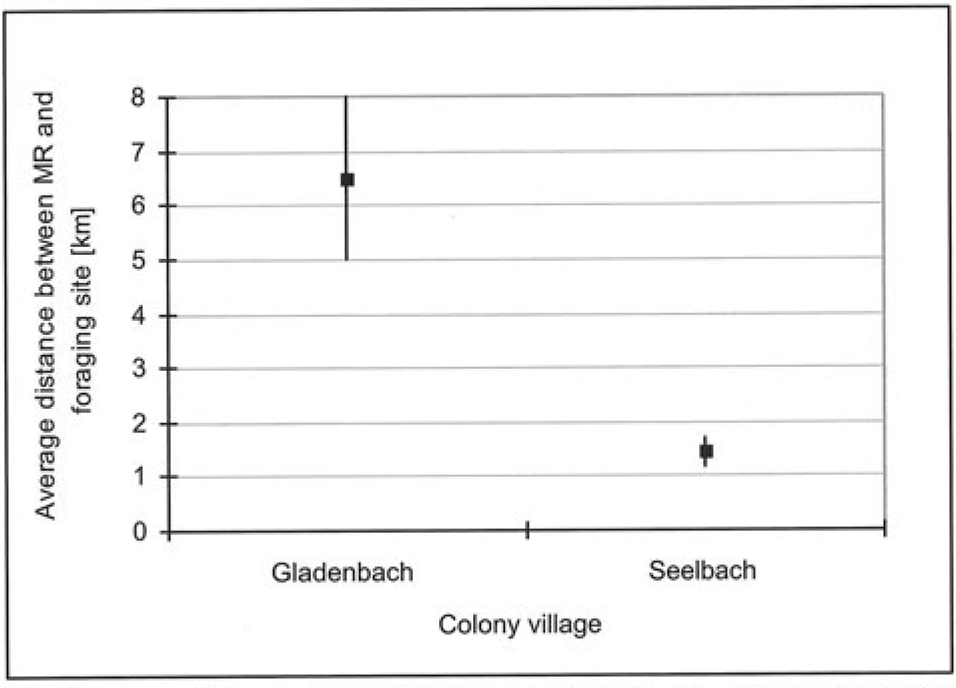

Figure 145: Average distance (including 95 % confidence interval) between maternity roost and foraging sites in Gladenbach and Seelbach.

7.3.3 Whiskered bat

According to the literature the foraging sites of the whiskered bat are situated on the one hand at forest edges, in hedges and in riparian vegetation along inshore waters (DE JONG 1995, GODMANN 1995, RICHARZ 1994, TAAKE 1992, TRAPPMANN 1996, ZAHN & MAIER 1997). On the other hand, animals were observed hunting in forests (NYHOLM 1965, LIMPENS &

KAPTEYN 1991, GODMANN 1995). NYHOLM (1965) ascertained that the preference for a certain type of foraging site changed according to season: whereas the whiskered bat favoured forest habitats from May to July, from the end of July onwards this bat was more likely to be found in open country and along inshore waters. The only known radio telemetry study was carried out by GODMANN (1995), who found the whiskered bat hunting in forests (oak-beech forests) and forest edges, and also in riparian vegetation along inshore waters.

The home range of the whiskered bat can be 20 ha (GODMANN 1995) or 6.15 to 34.5 ha (NYHOLM 1965).

The distance from roost to foraging site can be between a maximum 650 m (GODMANN 1995) or 700 m (average 187 m) (NYHOLM 1965) or 1,100 m (LIMPENS et al. 1997).

One female whiskered bat tracked in this project used a total 6 distinct foraging sites, all of which were in forests (predominantly oak and oak/beech forests). The average distance between roosts in the town and the foraging sites was 980 m (maximum 1,250 m).

7.3.5 Natterer's bat

The Natterer's bat hunts mainly in forests (deciduous, mixed and coniferous) (DE JONG 1995, LIMPENS & BONGERS 1991, SIEMERS & SCHNITZLER 1999), but also along the edges of forests, in rows of trees, and in hedges and shrubs (BECK 1991, LIMPENS & BONGERS 1991, SWIFT 1997). Additionally, the Natterer's bat hunts in open country, over green spaces and grain fields (TRAPPMANN 1996).

The homerange of individually tracked animals varied in area from 80 ha, 123 ha, and 523 ha (SIEMERS & SCHNITZLER 1999). Roost and foraging sites were up to 3.4 km apart (SIEMERS & SCHNITZLER 1999). TRAPPMANN & CLEMEN (2000/2001) established via radio telemetry that male Natterer's bats travelled 350 m to 1,000 m between roost and foraging sites while females travelled from 1,000 m to 1,500 m.

The three females tracked in this project hunted in forests (deciduous, coniferous and mixed), on hedges, in a cowshed and in a shed (see chapter 11.2.3). The maternity roost and foraging sites were situated between 350 m and a maximum 2,430 m apart. The bats also used hedges and vegetation along water courses as connecting lines between roost and foraging sites or as a connection between two foraging sites (see chapter 11.3).

7.3.6 Barbastelle bat

Barbastelle bats prefer to hunt in forests (SIERRO 1999, STEINHAUSER 2002). Individual animals were observed at a shrub-lined stream (HEDDERGOTT 1992a). Moreover, linear green structures (tree-lined lanes, tree-lined water courses and tree-lined pasture) together with traditional extensive agricultural land uses (orchards, meadows) are said to be of importance to barbastelle bats (RICHARZ 1989). STEINHAUSER (2002) reported that tracked barbastelle bats hunted in the lower to middle canopy area (average height 10 m) in forests and along linear structures in heights from 1.5 m to 6 m, and that they partly used forest paths as connecting lines between foraging sites. The maximum home range area of individual animals was 5 km. Nine tracked animals used a total area of 35 km². The distance between roosts in the forest to foraging sites was under 1 km for males and between 3 km and 4.5 km for females.

SIERRO (1999) observed barbastelle bats hunting above the tree canopy and ascertained that the animals show fidelity to their individual foraging sites.

The seven barbastelle bats tracked for the purposes of this study used a total 24 distinct foraging sites, whose size varied between 2 ha and 48 ha (see chapter 11.2.4). Each invidividual bat visited from one to seven foraging sites. The percentage of foraging sites made up by forest varied between 68 % and 100 %. Deciduous, coniferous and mixed forests were used. The remaining foraging sites of significant area were in open country.

The distance between maternity roost and foraging sites was between 0.8 km and 8.2 km (average distance 3.9 km).

7.3.7 Grey long-eared bat

Forests, forest edges, orchards, hedges, gardens and villages have all been named as potential foraging sites for the grey long-eared bat (CASTOR et al. 1993, FLÜCKIGER & BECK 1995, JANSEN 1993, KIEFER & VEITH 1998).

The homerange of an individual can range from 6.16 km² (FLÜCKIGER & BECK 1995, a radio-tracked female) to 9.3 km² (HURKA 1989 in MESCHEDE & HELLER 2000).

The foraging sites are sometimes in close proximity to the roosts and sometimes up to 5.5 km away (KIEFER & VEITH 1998, FLÜCKIGER & BECK 1995).

The foraging sites of the females from two villages radio-tracked for the purpose of this study were forests, tree-lined water courses, a shrub-filled road embankment and gardens on village outskirts. The foraging sites were situated not only close to the village (250 m from roost) but also up to 3,250 m from the roost.

7.4 The summer move to another roost (level 3)

7.4.1 Common pipistrelle

The spatial borders of a maternity colony were discussed in Chapter 7.2.2.1. As a rule, a small village will contain one fairly exclusive maternity colony, which in bigger villages can divide into two sub-colonies. In towns where the roosts were less than 1,700 m apart, there was a minor exchange of individuals (two to 7). In four further neighbouring villages containing maternity colonies (1,900 m to 3,600 m apart), banded bats were recaptured only in the village of original capture, not in a neighbouring village (see figure 146). Now and then

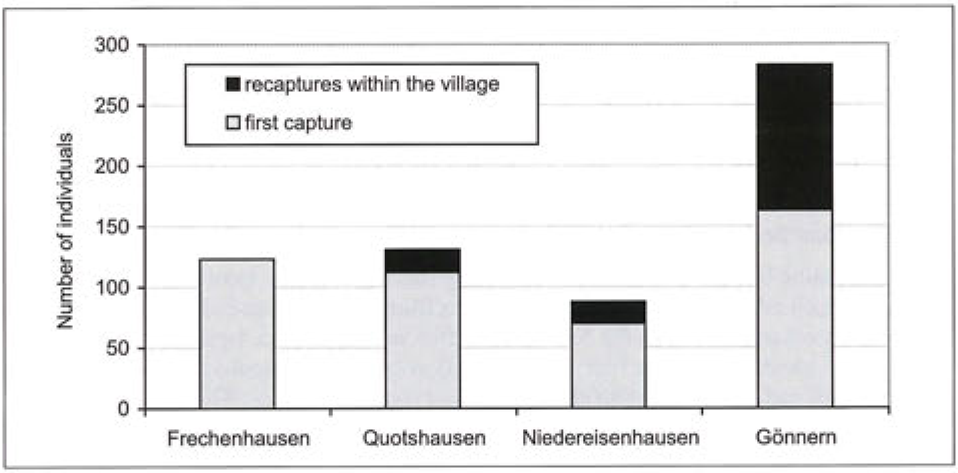

Figure 146: Number of capture and recaptures of common pipistrelles (individuals) in the villages Frechenhausen, Quotshausen, Niedereisenhausen and Gönnern.

in the course of the project a bat would be recaptured far away from its maternity roost. This can be interpreted as the summer move to another roost. A total 28 individuals changed to a different roosting colony between 1997 and 2000. To this purpose they travelled up to 29.6 km (linear distance) within the project area (see figures 147 and 148). If these common pipistrelles are differentiated according to age, the adult females flew an average 7 km between first roost and second, where as the females who were juveniles when first captured in one roost were recaptured in the following years in roosts an average 3.7 km away from the original location (see figure 149).

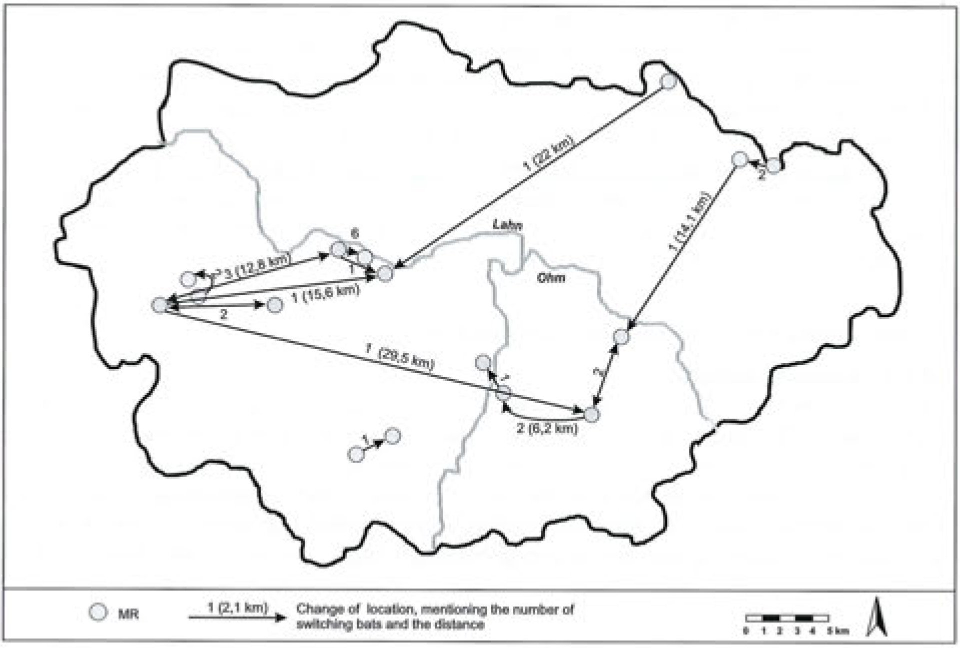

Figure 147: Change of location between maternity roosts (MR) of adult common pipistrelle females in the project area over the years 1997–2000.

7.4.2 Serotine Bat

When serotine bats were captured in maternity roosts in villages between 2 km and 4 km away from each other, there were some recaptures from each particular village, but there was no proof of exchange between the colonies in different villages (see figure 136).

A summer move by serotine bats to a maternity roost in a different village could only be ascertained by radio-tracking individual bats (n = 3) (see figure 150). The bats radio-tracked to a different village were not found in the maternity colony there but rather in individual roosts. Two of the three radio-tracked animals returned to their original maternity roost. One further proof of location change was a serotine bat ringed in 1994 and rediscovered in a tudor-style house in November 1997 during renovations.

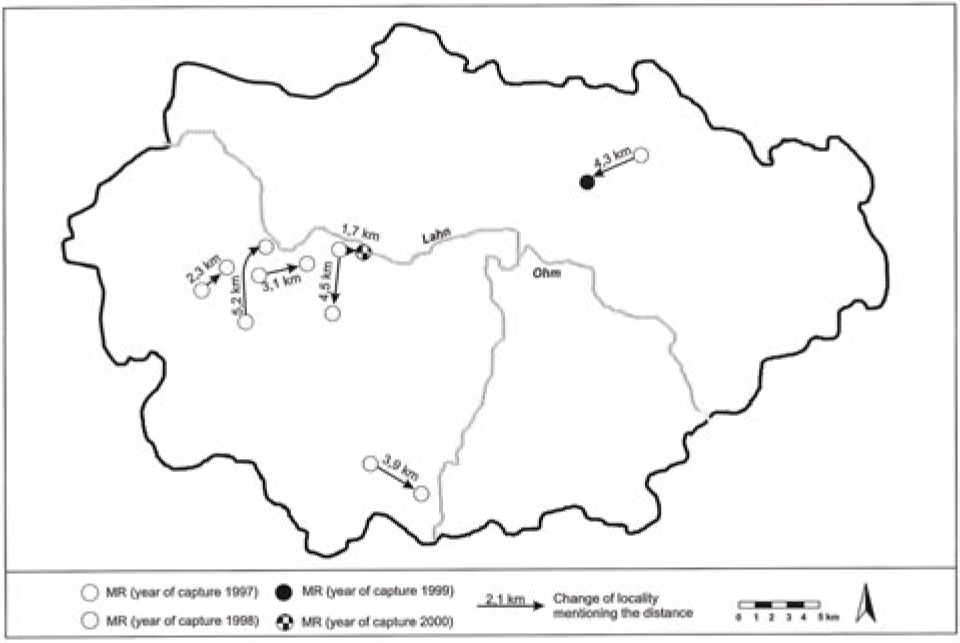

Figure 148: Change of location between maternity roosts (MR) of juvenile common pipistrelle females (n = 7) in the project area over the years 1997–2000.

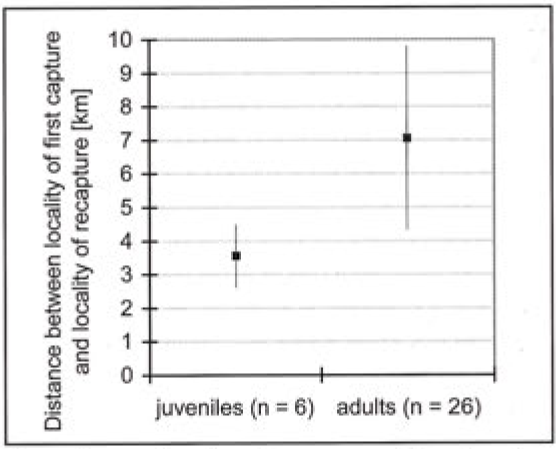

Figure 149: Average distance between location of first capture and location of recapture (with details of the 95 % confidence intervals) travelled by juvenile and adult common pipistrelles in their summer move to another maternity roost.

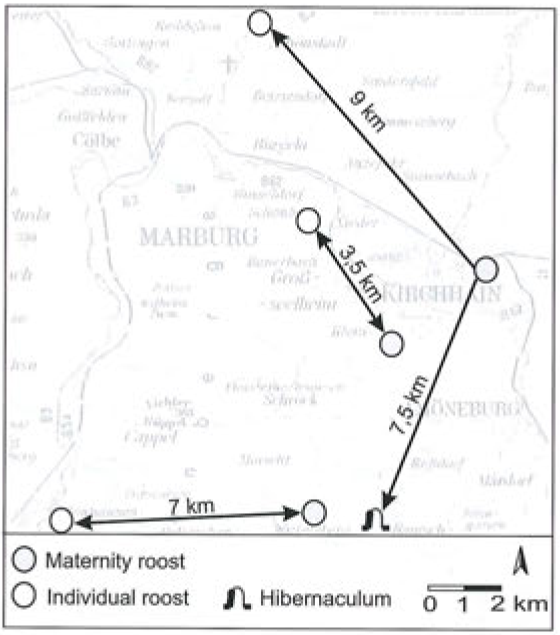

Figure 150: Move to another village (n = 4) over the years 1997–2000. Evidence for the summer move to a different maternity roost or individual roost was provided exclusively by radio-tracked bats. Proof for a move to another village to a hibernaculum was provided by a serotine bat banded in 1994 and rediscovered in November 1997 during renovations.

7.4.3 Greater mouse-eared bat

Apart from a regular exchange of individuals between various maternity roosts within a radius of 16 km, spatial relationships were found to three further maternity roosts up to 400 km away (Linear distance, see figure 151). These animals were not added to the number counted for the maternity colony, but rather were added to the statistics for a summer move to a maternity roost in a different village. Thus a female greater mouse-eared bat banded as a juvenile by KALLASCH/NATUSCHKE in 1995 in Bertelsdorf, Saxony, was recaptured in the greater mouse-eared bat colony in Gladenbach (400 km away). A female banded in Gladenbach was recaptured in a colony in Bavaria 162 km away (oral statement by HAMMER). These recaptures illustrate how huge the range of activity in greater mouse-eared bats can be at the level of maternity colony alone.

Along with connections between various maternity colonies there are also special relationships between maternity roosts and mating roosts. One female travelled 60 km from her maternity roost to her mating roost (see figure 152; recapture written statement KOLODZIE). She hibernated in a gallery approximately 8 km south of her mating roost (recapture written statement BUCHEN) and was found again in her original maternity colony in summer. This female could be repeatedly found over the years in the same mating roost (written statement KOLODZIE).

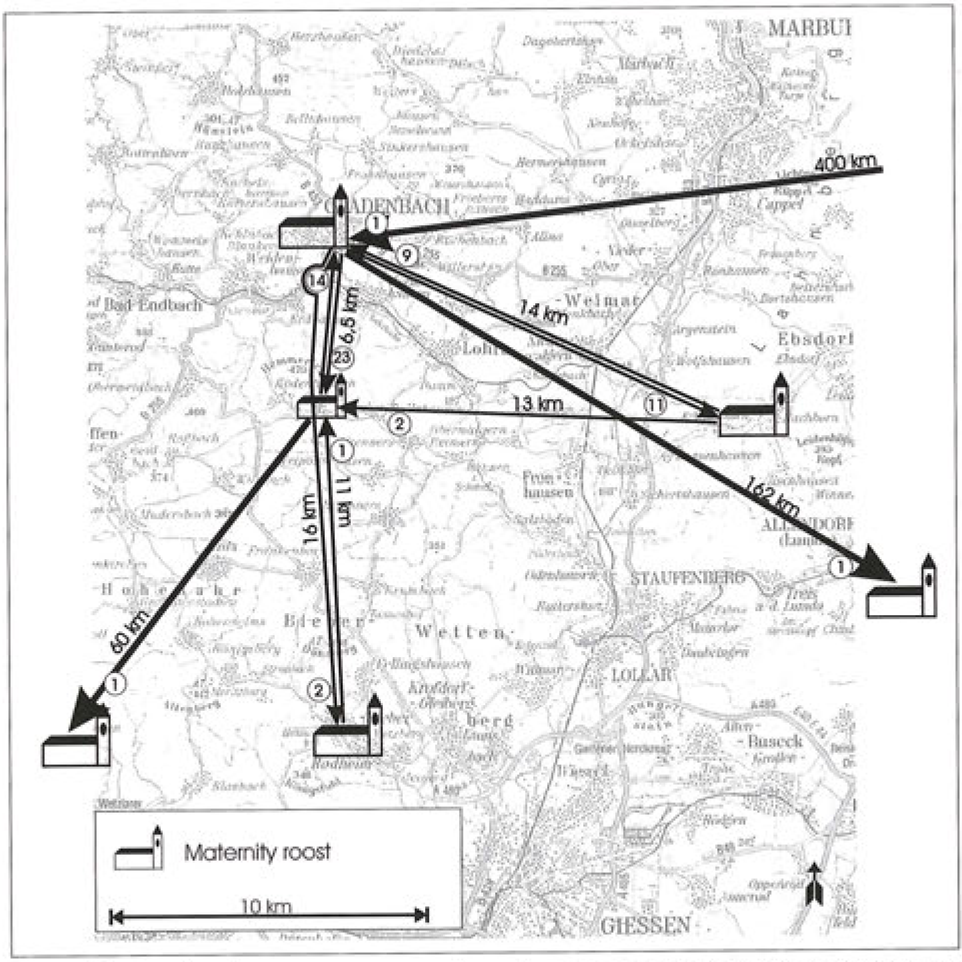

Figure 151: Overview of proven summer moves by greater mouse-eared bats (n = 65) to a maternity roost in a different village between the years 1998–2000. The numbers in circles give the number of moves. A total 40 individuals are involved. An exchange of individuals between colonies within 16 km takes place regularly (colony assemblage). The three spatial connections to maternity roosts further away are rated as summer moves to a different colony by the greater mouse-eared bat.

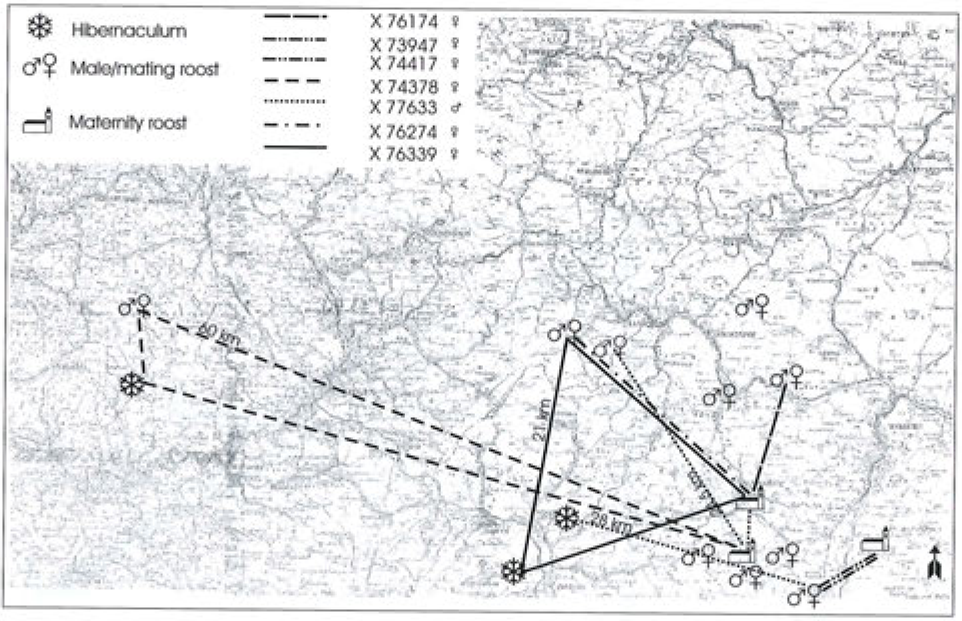

Figure 152: Spatial relationships of seven banded greater mouse-eared bats between maternity roost, mating roost and hibernaculum.

7.5 Spatial relationship between summer roost and hibernaculum (level 4)

7.5.1 Common pipistrelle

Within the project area common pipistrelles were captured and banded in a mass hibernaculum in the Marburg Castle and also in 38 other villages with maternity roosts. Additionally, common pipistrelles were captured in three different locations outside the project area (without being banded). Banded individuals proved a spatial relationship between the hibernaculum in Marburg and 33 (87 %) of the 38 locations in the project area (see figure 153). The common pipistrelles from most maternity roosts obviously inspected the castle in summer and later used it as their hibernaculum. It could not be proved that all individuals from a maternity roost carried out the reconnoitre exercise at the castle or that all went to the same hibernaculum.

It is conspicuous that, despite many captures, no spatial connection could be made between the hibernaculum and the three maternity roosts in locations in the Upper Lahn Valley (see figure 153). It can be assumed that these common pipistrelles are situated in the catchment area of a different hibernaculum and that this is why none were found in the Marburg Castle hibernaculum.

Individual bats banded in the Marburg Castle were recaptured in two of the three locations just outside the project area. The maximum distance between a maternity colony and the mass hibernaculum could thereby be set to 59 km.

By means of "long-distance radio-tracking" of common pipistrelles banded in their maternity roost and recaptured in their hibernaculum in summer, it could be shown that the bats flew back to their colony location in the same night that they reconnoitred the castle (see chapter 6.3). To do this they covered distances up to 22 km (linear distance).

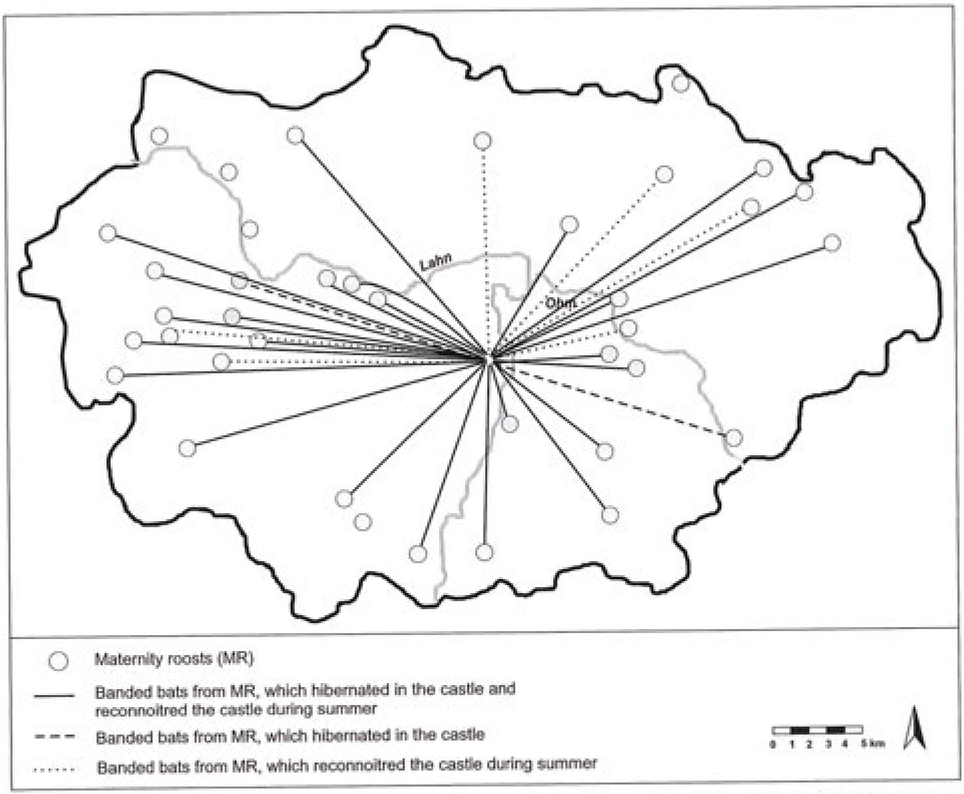

Figure 153: Spatial relationship between maternity roosts (n = 33) and the hibernaculum Marburg castle, demonstrated by over 379 banded individuals.

Aside from the targeted recaptures in maternity roosts in the project area, the so-called chance findings of banded common pipistrelles were also evaluated (e. g. findings reported by honorary conservationists or citizens. These common pipistrelle findings made up only a small percentage of total recaptures. Of the approx. 15,800 common pipistrelles banded since 1996, only 0.37 % (n = 59) were chance findings. Among these were several long-distance findings, discovered more than 50 km from the banding location (see figure 154). A further 18 common pipistrelle findings were reported up to the close of the project in 2002, but these all came from the vicinity of Marburg.

7.5.2 Greater Mouse-eared bat

By reason of a partly intensive banding of greater mouse-eared bats in the 1950's, it was possible to have several long-distance findings. HUMMITZSCHE (1960) could show that a banded bat from one maternity roost was found three years later in a hibernaculum 154 km away. EISENTRAUT (1960) demonstrated the enormous distance achieved by a juvenile male greater mouse-eared bat in one season, which was found in a hibernaculum 225 km away from its maternity roost. From observations over several years, EISENTRAUT (1960) ascertained a distance between maternity roost and hibernaculum of 260 km. The greatest distance

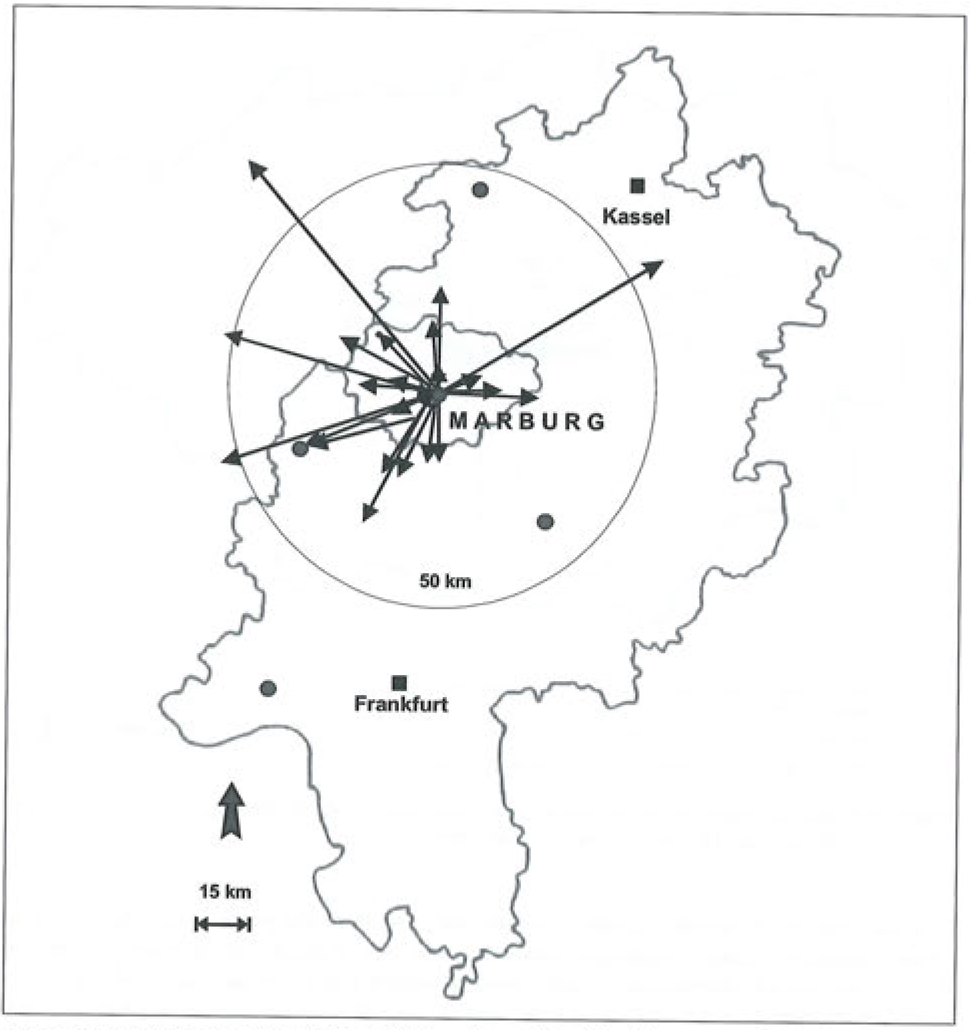

Figure 154: Location of reported chance findings (n = 59) of banded common pipistrelles (total n = 15,838) (as of 10. 10. 1999). By the end of the project (in 2002) a further 18 findings were reported, all of which came from the Marburg vicinity. The circle indicates a 50 km radius.

between maternity roost and hibernaculum reported was in the investigations of ZÖPHEL & SCHOBER (1999), namely 174 km.

The project found banded greater mouse-eared bats in hibernacula up to 28 km away (chance findings not considered) (see figure 155). Bats were observed in part hibernating, hanging from the ceiling of a gallery, and in part were captured with nets in summer when swarming in front of the entrance to the gallery (reconnoitre of hibernaculum). Chance findings located individual bats in hibernacula 100 km and 116 km away (from maternity roost). If one observes the total spatial relationship between summer roost, mating roost and hibernaculum, then a complex network becomes evident (see figures 151, 152 and 155).

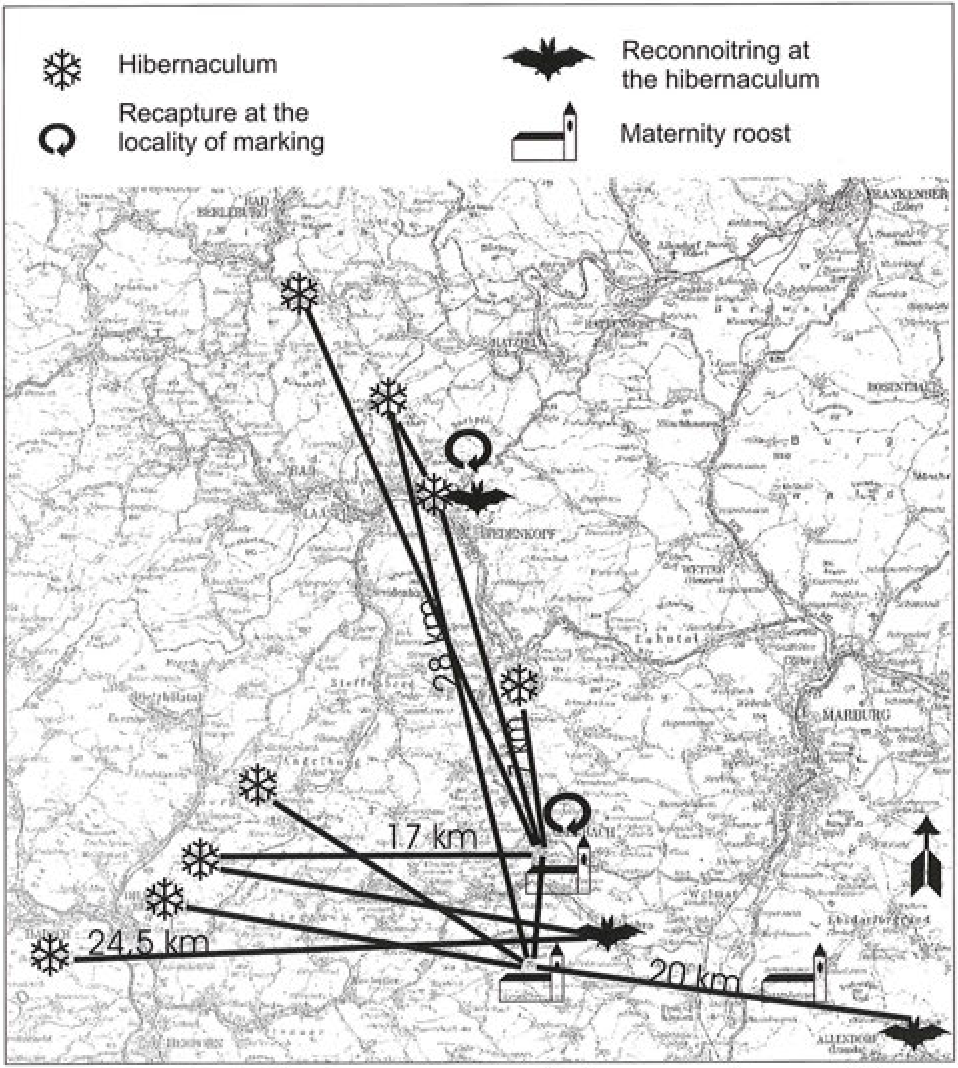

Figure 155: Spatial relationship of the greater mouse-eared bat between maternity roost and hibernaculum, evidenced by banded bats.

7.6 Consequences for conservation

As an introduction to a discussion of the consequences of the spatiofunctional relationships of bat populations, firstly the moves of these animals to different locations should be summarised according to season:

Winter: All individuals of a population spend the winter in hibernacula, however the animals of one colony may use many different locations in a region. Long-distance travelling species like the Leisler's bat, the Noctule bat and the Nathusius' pipistrelle may migrate across the greater part of Europe. Some bats change their roost regularly during winter. With some species the majority of a region's population will gather in a central mass hibernaculum (e. g. common pipistrelle, Natterer's bat).

Spring: After hibernation, mostly small groups of bats gather in various roosts, designated by some authors as interim roosts. The first females then arrive at the maternity roosts. The females of many species of bats return to exactly the same maternity roost in which they were born (common pipistrelle, serotine bat, Bechstein's bat, Leisler's bat, noctule bat), so that the colonies consist mainly of bats closely related. Meanwhile the males remain alone in individual roosts. Only few species form group male roosts (e. g. pond bat). From mid-May to the end of May the number of bats in the maternity roosts increases, and then divides again into smaller groups. In the common pipistrelle, the females gather in a central maternity groups for the time they suckle their young, but divide into smaller groups before and after this time. In the greater mouse-eared bat species, many females who have no young of their own seem to leave the maternity roost before the birth period. Individual females make short stays in various maternity roosts in a region.

Summer: Several species of bat change their roost every few days during the maternity period, namely common pipistrelle, serotine bat, barbastelle bat and others. These maternity colonies use an assemblage of several roosts in close proximity to each other (average distance apart is approximately 150 m with common pipistrelles and 30 m to 300 m with serotine bats). In the common pipistrelle and greater mouse-eared bat, some females even change maternity colonies. Common pipistrelles can travel up to 30 km to do this, however the average distance is 7 km for adults and 3.7 km for one-year-olds. Little groups of greater mouse-eared bats do occasionally change to another colony, travelling up to 16 km to do so. When colonies are within 10 km of each other, a more frequent exchange of individuals can be assumed. The Natterer's bat appears to stay in the same maternity roost, at least those in cowsheds. Serotine bats apparently very rarely change to another colony. To search for food, the females of maternity roosts fly to foraging sites which are situated in the vicinity of the maternity roosts. The distance flown from maternity roost to foraging sites depends on the species of bat and the size of the colony. The maximum distance flown between roost and foraging site is approx. 2 km for the common pipistrelle, the serotine bat, the Natterer's bat and the whiskered bat; 8.2 km for the barbastelle bat; and 13.8 km for the greater mouse-eared bat (large colony). While the females rear their young, the males start to reconnoitre known and potential hibernacula in the area. Common pipistrelles can travel up to 22 km and greater mouse-eared bats up to 28 km from their roost to the hibernaculum, at which they swarm during one night.

High and Late Summer: After the maternity period the females start to reconnoitre their hibernaculum and fly many kilometres to do so, for example 59 km for common pipistrelles. At this time new day roosts are visited, in which the bats sleep alone or in small groups. After they have reconnoitred their hibernaculum, the adult bats visit special mating roosts, which can be at a great distance from the maternity roost, e. g. 60 km for greater mouse-eared bats. In late summer the young bats reconnoitre the hibernacula, to which they apparently are led by adult animals. Sometimes thousands of juveniles can be observed swarming at a mass hibernaculum, especially on a warm night. The swarming bats come directly from their summer roosts which are located within a 40 km radius of the hibernaculum, and fly back in the same night. The actual exploration of the hibernaculum itself usually takes less than 15 minutes.

Autumn: After the mating and swarming period, bats seek small roosts in close proximity to the mating roost or hibernaculum, or fly directly to their hibernaculum.

This newly won knowledge about the movements of the various house-dwelling bats highlights the impressive mobility of these animals. No other animal can demonstrate such a varied, extensive and regularly changing utilisation of space. Prerequisite for the mobility of bats is their detailed knowledge of several areas in a region as well as the ability to pass on information on the location of suitable roosts. This mobility is tied to a formation of traditions, for bats are very loyal to the same roosts over their often long lifetimes. Our investigation could only provide a description of their complex, highly developed ethological and ecological adaptation – other studies will have to provide an explanation for these phenomena and their mechanisms.

Conservation of bats must take into consideration both their spatial relationship to the landscape and their living places within it (roosts, foraging sites), and also the bat's special abilities (mobility, ability to form traditions) and needs. The different levels of spatiofunctional relationships and the seasonal life cycles of bats must be taken into consideration if measures to conserve bats are to be effective. These basic premises for the preservation of house-dwelling bat species mean in detail the following:

Offer many summer roosts

Each bat requires several summer roosts to which it can change according to weather, social factors or other reasons. Since house-dwelling bat species have differing requirements for roosts, the maximum possible number of a maximum possible variety must be available. Most urgent is of course the preservation of existing roosts regularly used by bats. Parallel to this must be the continual creation of new (potential) roosts, because existing roosts continually are being destroyed or are no longer habitable. Natural weathering or particular building methods create new roost possibilities for some, mainly crevice-dwelling, bat species. However, it is questionable today whether these can make up for the constant loss of roosts. For this reason it is meaningful and in many areas of human settlement essential that potential roosts be deliberately created, alongside the maintenance of current roosts. In view of the high number of roosts needed by local bat populations in summer for their maternity colonies and single males, it is not possible to satisfy this demand by institutional conservation measures. The T&D project could only increase the offer of roosts only here and there. For this reason, help from citizens is essential for bat conservation. In order to preserve current and potential roosts, house owners and construction workers are required to show tolerance towards their largely uninvited guests and to have a certain sensibility to their needs. Additionally, the creation of new potential roosts should be constantly promoted. Public awareness campaigns for bat conservation as developed and successfully tried out in the T&D project play a central role in the protection of house-dwelling bats. Institutional conservation should concentrate its resources on preserving the maternity roosts of greater mouse-eared bats (and horseshoe bats) which are usually situated in large-scale areas under roofs.

Secure roost assemblage for maternity colonies

A maternity colony requires several suitable roosts in close proximity, because common pipistrelles and serotine bats, for example, change their maternity roosts frequently. Preserving the roost assemblage is the most pressing task in bat conservation. The bigger the assemblage of habitable roosts, the surer a colony's survival, because the bats have an alternative if a roost becomes uninhabitable. It is not enough to preserve individual roosts. Extensive redevelopment programs can destroy several elements of a roost assemblage at one time and thus have devastating effects on bat populations. Greater mouse-eared bats usually only have one maternity roost per colony, but there is a roost assemblage with tree hollows in foraging sites where bats from the maternity roost often spend the day. Therefore, these tree hollows must also be preserved. It follows that in order to preserve the roost assemblage, it is imperative to have specific knowledge about the number and type of roosts, the size of the maternity colony and the homerange of each bat species. Local bat experts and roost caretakers could provide this knowledge, but primarily, in most villages and towns, there needs to be a systematic investigation into the local bats and their roosts. Such special bat mappings should have the mapping of the maternity roosts as their most essential element, whether or not they are ordered for the purpose of construction plans or urban habitat mapping. The location of foraging sites, flight paths and male roosts are less important (in that order) for bat preservation in areas of human settlement.

Enable inter-colony assemblages

The bat population or maternity colony of a village or suburb can only survive in the long term if it has a (genetic) exchange with bats of the same species in other areas. As well as mating with males from other areas, there needs to be a regional or inter-regional exchange of females between maternity colonies, and this should be made possible. As a consequence, it is not enough to save one isolated roost assemblage if the aim is to secure a bat population in the long-term, when there are no other neighbouring colonies within reach with which a colony assemblage can be formed.

Conserve foraging sites

House-dwelling bats must find suitable foraging sites in the vicinity of their summer roosts. These foraging sites must be easily reached by the bats, offer enough food sources and fulfil other conditions according to the needs of each species (e. g. wind protection for long-eared bats, darkness for greater horseshoe bats). Old timber stands, in particular, are good food sources for the nocturnal insect hunters, as are orchards on the outskirts of villages. Long-eared bats, Natterer's bats, common pipistrelles and serotine bats can all be found in the parks and gardens of areas of human settlement. Those responsible for upkeep of green areas in villages and towns should take this into consideration, or even better, promote a rich insect and spider fauna through provision of a rich variety of flora and use of only moderate garden maintenance practices.

Conserve local biotope assemblage

Summer roosts and foraging sites form one unit for bats. The former are connected by flight routes. Some maternity colonies fly from their assemblage of roosts along the same route to their foraging sites every evening and thereby use so-called flight paths. They orientate themselves by using certain landmarks (e. g. old trees, water courses) or travel along hedges and rows of trees that act as windbreaks. Such flight paths and the structures along them connecting roost to foraging sites must be preserved. These flight paths may take house-dwelling bats far out of the settled area into the fields (e. g. with serotine bats) or to the forests (e. g. with greater mouse-eared bats). An interruption in the connection between roosts and foraging sites would be to cut their habitat in half (habitat fragmentation) and this could threaten the bats' survival. Some bat species are especially sensitive to road traffic, so that a new road can form an almost insurmountable barrier. When there are plans to change the landscape or intervene in the biotope assemblage, then it is necessary to first gather information on the regularly used flight routes and flight paths of the local bat populations, obtained by targeted mapping.

Conserve the regional biotope assemblage

Not enough is known about the direction and routes taken by bats to get to neighbouring colonies, mating areas and hibernacula. It can be assumed, however, that in these (sometimes lengthy) journeys, a role is played by landscape structures and individual landmarks. Further research of this is needed, but important elements of the landscape around many significant mating areas and hibernacula can already be recognised and protected (e. g. valleys with a river or stream running through them; edges of forests). A colony assemblage can be supported by maintaining and developing an appropriate biotope assemblage along the supposed flight routes (e. g. an avenue of trees lining a farm road between two villages). Finally, comprehensive bat conservation requires that consideration be shown for this group of animals when plans are made to change the landscape.

Conserve hibernacula

Finally, sufficient suitable, accessible hibernacula must be available within easy reach for every bat population. Particularly in areas of human settlement, the hibernation possibilities have drastically decreased over the last decades. Old cellars with vaulted ceilings, very suitable sites, are now only seldom accessible to bats, and new buildings offer less and less hiding places safe from frost. Species like long-eared bats which as a rule travel only short distances to their hibernaculum suffer particularly from this phenomenon. Therefore, the preservation of existing hibernacula is of the utmost importance. When the hibernacula are in areas of human settlement, the same applies to this task as to the summer roosts: institutional conservation is not in a position to undertake the countless steps necessary. Rather, targeted public awareness work must get house owners themselves involved, for example in that they purposefully leave an existing hibernaculum unchanged. The phenomenon of invasion should be explained and instructions provided for correct behaviour should this event occur. Significant bat hibernacula like the mass hibernacula of the common pipistrelle deserve the particular attention of conservation bodies. These hibernacula should be protected by law and secured from trespassers, where this is realistic. It would make little sense, for example, to undertake extensive security work in a parking station or private residential building. The same principle applies to hibernacula outside villages and towns. Many caves and galleries used as hibernacula already have been gated off by bat conservationists or local councils. Now further steps need to be taken to preserve the other spatiofunctional relationships of bats.

7.7 Summary

Summer roost assemblage of common pipistrelles

Table 31 provides a summary of data available on the roost assemblage of common pipistrelles.

- A total 120 moves over three years were observed between 9 maternity roosts by common pipistrelles (n = 45) banded in 1998.
- A move to another maternity roost was made by juvenile, sub-adult and adult banded common pipistrelles.
- As a rule there is one maternity colony per village (a village having up to 530 buildings). In other words, common pipistrelles move to different roosts (groupwise) only within the same village. In larger settlements (having more than 330 buildings, 0.6708 km^2), a colony can split into two sub-colonies which use roosts very close to each other. An exchange of individuals between colonies in different villages occurs only in isolated cases.

Table 31: Data on roost assemblage of common pipistrelles.

	Kleinseelheim	Wittelsberg
Area	0.2963 km^2	0.6708 km^2
Number of buildings	257	340
Maximum of ad.+sub-ad. bats per village	66	180
Maximum of ad.+sub-ad. bats per roost	48	108
Number of maternity roosts	29	25
Maximum of used maternity roosts per year	16	14
Number of maternity roosts used at least in two years	12	14
Maximum number of simultaneously used roosts	3	6
Average time period of sojourn per roost	6 days	5 days
Maximum time period of sojourn per roost	26 days	39 days
Average distance between roosts [m]	157	331 (158 / 145 within the two sub-colonies)
Are two sub-colonies established?	no	yes

- The common pipistrelles maternity colonies split up before and after lactation into several roosts, but use a common roost during lactation.
- Over the years the common pipistrelles often use the same roosts at the same time of year (phenology of moves to different roosts).
- The common pipistrelle's move to a different roost occurs in one night. In the night of the move and the following night, in which no more animals fly out of the old roost, there netherthless occur numerous flights in and out.

Roost assemblage of the serotine bat

Table 32 summarises the important facts on the roost assemblage of serotine bats. The building complex in Marburg with its numerous crevices for potential roosts, contains an exceptional 31 "maternity roosts".

- In total the serotine bat uses less roosts than the common pipistrelle, but uses each one several times in one season. One can differentiate between main roosts, which are used up to seven times in one season and supplementary roosts which are visited once or twice in the maternity period.
- The chronological order in which the roosts were used was similar over several years (phenology of moves to different roosts).
- No exchange of banded individuals was observed between other colonies, which were in part in neighbouring villages.
- Nocturnal phenology of the move to a different roost was observed during a night watch at a roost complex. The serotine bats displayed moderate activity during the night and

Table 32: Data on roost assemblage of serotine bat.

	Kirchhain	Großseelheim	Marburg
Maximum of ad.+sub-ad. bats (emerging)	60	39	48
Maximum of ad.+sub-ad. bats per roost	57	39	37
Number of roost switching	16	7	18
Average roost switching	6 days	6 days	3 days
Number of maternity roosts	6	9	31
Maximum of used maternity roosts per year	6	9	31
Average distance between roosts [m]	260	110	Building complex < 30

increased their activity in the early morning hours, in the form of frequent flights in and out of the roost.

Colony assemblage of the greater mouse-eared bat

- In contrast to common pipistrelles and serotine bats, the greater mouse-eared bat does not move together in middle-sized to large groups to a new roost in the immediate vicinity (roost assemblage). Rather, in summer the greater mouse-eared bat moves alone or in small groups to a different colony in a different town/village (colony assemblage). Distances of up to 16 km linear distance are regularly surmounted to make the move between maternity roosts. Over the years 1998 to 2000 a total 62 moves by 37 individuals could be documented.
- The largest colony (300 adult females) had the smallest percentage of movers (emigrants and immigrants), namely 3 % to 11 % per year. The percentage of movers in the smallest colony studied (30 adult females) was the highest, being between 23 % and 66 % per year.
- In addition to their maternity roost, the majority of the tracked greater mouse-eared bats used a further 19 different day roosts, which were situated 2.9 km to 12.8 km away from the maternity roost. Four of these day roosts were in buildings.
- During the maternity period, small groups of females can spend the day in tree hollows.

Roost assemblages of remaining species

- A direct proof of the **whiskered bats'** move to a different roost was provided by a tracked female.which moved from a maternity roost behind a slate wall to a roost in the forest. Besides this, the decreasing numbers of bats in known roosts points to the usage of at least one further maternity roost.
- The **Natterer's bats** moved back and forth several times between two roosts within the same cowshed (crevices in the breezeblock ceiling), but were present in the cowshed without interruption from the end of April to the end of June. Then all animals left the building and did not return that year. Only short stays were registered in roosts found in other buildings.

- The **barbastelle bats** used at least 13 different locations behind a building's slate wall between 17th April and 23th August 2000. The colony was made up of 39 adult females. A maximum 67 animals were counted at the time the young made their first attempts to fly. Whereas up to the end of May the barbastelle bats constantly moved to different roosts on the building, in June they stayed almost exclusively in one spot behind the slate wall. A maximum of four crevice roosts were used at any one time. Presumably this building (an old manorhouse) has served a long time as a site for the barbastelle bats' maternity roost (assemblage). It has been used by them every year since the discovery of the maternity roost in 1998.
- A radio-tracking investigation of **grey long-eared bats** could follow the move of two bats, each in a different village, between two buildings in close vicinity (10 m and 50 m apart, respectively).

Utilisation of foraging sites

- 95 % of the foraging sites of the common pipistrelle, serotine bat, Natterer's bat and whiskered bat are situated within 2 km of the maternity roost (see figure 156). The average distance was between 840 m (common pipistrelle) and 1,500 m (Natterer's bat).
- Barbastelle bats and greater mouse-eared bats cover significantly greater distances to reach their foraging sites (maximum 8.2 km and 13.8 km, respectively).
- The average nocturnal stay of the **common pipistrelle** in its roost was 12 % of the night (40.3 minutes). Lactating females spend the longest period of the night in their foraging sites (77 %), while pregnant females spend only 61 % of the night in their foraging sites.

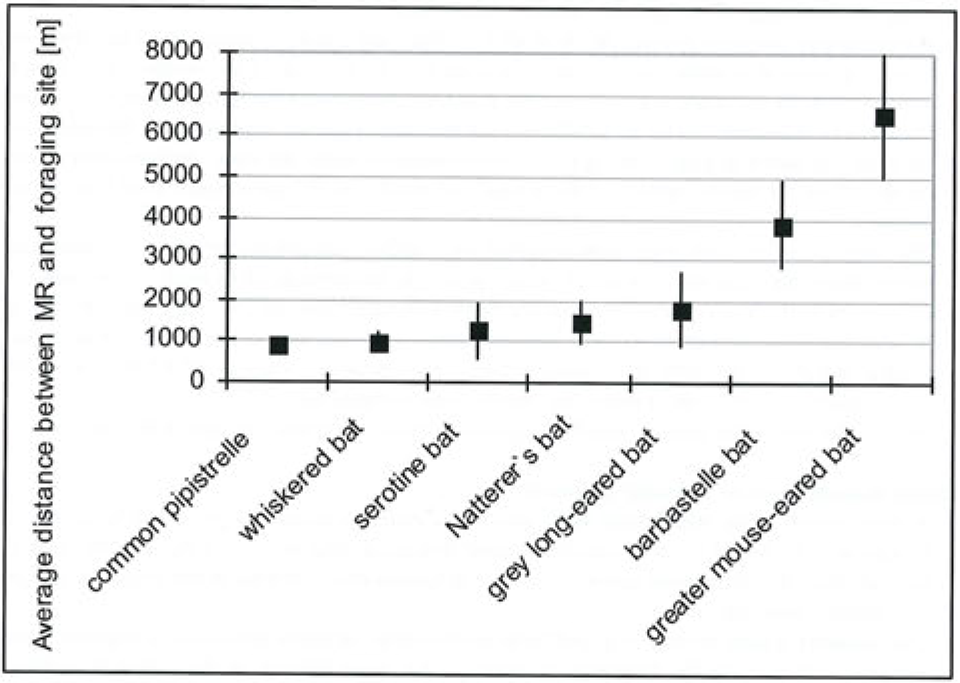

Figure 156: Average distance (including values for 95 % confidence interval) between maternity roost (MR) and foraging sites of all bat species investigated.

- A large colony of **greater mouse-eared bats** consisting of up to 300 females had a significantly larger homerange (155 km²) than a smaller colony of 30 adults (10 km²).
- 95 % of the foraging sites of the **greater mouse-eared bat** were in forest, 4 % in open country.
- While the foraging sites of the smaller **greater mouse-eared bat** colony were less than 3 km away from the maternity roost, the foraging sites of the large colony (up to 300 bats) were up to 13.8 km away.
- A female **whiskered bat** radio-tracked as part of the project used a total 6 foraging sites, all located in forest (predominantly oak and oak-beech forest).
- The three female **Natterer's bats** radio-tracked as part of the project hunted in forest (deciduous, coniferous, mixed), on hedges, in a cowshed and in a shed. In addition the bats used hedges and vegetation along water courses as connecting lines to their foraging sites or between different foraging sites.
- The seven radio-tracked **barbastelle bats** used a total of 24 distinct foraging sites which varied in size from 2 ha to 40 ha. Each individual bat visited one to seven foraging sites. The percentage of forest area in the foraging sites varied between 68 % and 100 %, whereby deciduous, coniferous and mixed forest were used.
- The foraging sites of radio-tracked female grey **long-eared bats** were situated in forests, vegetation along water courses, at a shrub-filled road embankment in gardens on the outskirts of the village.

Summer move to another village

- Over the years 1997 to 2000 a total 28 **common pipistrelles** moved to a maternality colony in a different village. To do this they flew up to 29.6 km (linear distance). The average distance for adult females between site of first captur and site of recapture was 7 km, while females who were juveniles when first captured (at the first site) and were recaptured the next year in a different village had travelled an average 3.7 km to the new site.
- When **serotine bats** were captured in maternity roosts in villages between 2 km and 4 km away from each other, there were some recaptures from each particular village, but there was no proof of exchange between the colonies in different villages.
- Apart from a regular exchange of **greater mouse-eared bats** between various maternity roosts within a radius of 16 km (colony assemblage), spatial relationships were discovered to exist to a further three maternity roosts up to 400 km away (Linear distance). One female travelled 60 km from maternity roost to mating roost.

Spatial relationships between summer roost and hibernaculum

- A spatial relationship could be demonstrated to exist between the **common pipistrelles'** mass hibernaculum in Marburg and their maternal roosts in 33 (87 %) of the 38 villages in the project area, via banded individuals. The animals were captured either during the summer swarming or during emergences or entries in winter. The maximum distance between a maternal roost and the mass hibernaculum was 59 km.
- The **common pipistrelles** flew back to their colony villages on the same night in which they reconnoitred the castle, thereby travelling up to 22 km in one stretch.
- Chance findings of **common pipistrelles** reported by citizens made up only a very small percentage of recaptures when compared to targeted recaptures, namely 0.37 % of banded individuals compared to 31.26 % of banded individuals, respectively.
- Banded **greater mouse-eared bats** were recaptured at hibernacula up to 28 km away, either when hibernating or during the summer swarming. Chance findings were reported in hibernacula 100 km and 116 km away from maternity roosts.

Linear distances between the eleven pipistrelle bat colonies sampled ranged from 2 km to 37.5 km. Samples of the serotine bat came from all six colonies known in the study area. These colonies are located relatively close to each other with the exception of one colony, which was a maximum distance of 28 km from the other roosts.

For both species we examined the genetic structure of the nursery colonies and the correlation of geographic and genetic differentiation among colonies. Based on those results we can make inferences concerning the fidelity of females to their natal colony (natal philopatry) and the genetic exchange between colonies.

8.2 Basics of population genetics

8.2.1 Mitochondrial DNA

Genetic information in the form of DNA is not only found in the nucleus of cells. Mitochondria, which produce energy for cell functions by biochemical reactions, contain their own genome, which is reproduced independently and shows an almost exclusively maternal mode of inheritance. This means that only the genetic information of maternal mitochondria is transmitted to the offspring without recombination with paternal mitochondrial DNA. As a consequence, maternal lineages can be identified (WILSON et al. 1985, HARRISON 1989) which makes this marker especially suitable for population genetic analyses of nursery colonies (WILSON et al. 1985).

A further advantage of using mitochondrial DNA is the four times lower effective population size compared to nuclear DNA. This is due to two facts. Firstly, only half of the population, i.e. the females, are able to pass on their mtDNA. Secondly, mtDNA is haploid, i.e. only represents a single set of chromosomes. The lower the size of a population, the faster the effects of genetic drift (see below) will come into effect (BIRKY et al. 1983). It is possible that population structure is apparent on the mitochondrial level, even if populations are panmictic on the nuclear level. Particularly strong maternal differentiation should be found if females are philopatric, i.e. if they return to their place of birth for breeding (BIRKY et al. 1989, DESALLE et al. 1987, MAYER et al. 2002, WILSON et al. 1985).

8.2.2 Genetic drift and gene flow

Genetic drift and gene flow are of great importance for the genetic composition of populations. Genetic drift is defined as the random increase or decrease in the frequency of alleles (different forms of a gene or trait) within a population. Because not all individuals pass their alleles on to the next generation to the same degree, the genetic composition of a population or colony changes over time. This causes a gradual change in the distribution and frequency of alleles across populations. The effects of genetic drift are strongest in small populations – the fewer individuals in a population, the more random drift can act and the more quickly genetic variation will be lost. In the most extreme case genetic fixation occurs when all but one allele has been lost.

In opposition to the effect of genetic drift, gene flow increases or maintains genetic variation within a population (or colony). This occurs because individuals from other populations can bring in alleles that would otherwise be absent or rare in the population. One form of gene flow could be a female moving to and breeding in a colony other than her natal colony. Through such an exchange, new alleles might get transferred into a population (or colony), causing a local increase in genetic variation that can compensate for the loss of genetic variation due to drift.

In summary, genetic drift reduces the genetic variation within populations and at the same time increases the genetic differentiation between them. Gene flow, the introduction of new alleles to a population, can counteract this random loss of genetic variation.

8.3 Materials and methods

The amplification of specific DNA segments by polymerase chain reaction (PCR) is widely used in population genetics for the generation of sufficient amounts of probe DNA for analysis (MULLIS & FALOONA 1987). Tissue samples were obtained from the bats' wing membrane (plagiopatagium) using a sterile biopsy punch (Stiefel Laboratories). Biopsies were about 3 mm in diameter (WORTHINGTON WILMER & BARRATT 1996). Because the wing membrane has a high capability of regeneration, complete healing usually occurs within a few weeks (WORTHINGTON WILMER & BARRATT 1996). Accordingly, this kind of injury can be considered relatively harmless and shows similarities to natural injuries (for example caused by sharp-edged structures within the roost area).

Following amplification we sequenced about 250 base pairs of a non-coding region of the mitochondrial genome. Primers used had been developed previously for the noctule bat (PETIT et al. 1999). According to the basepair sequences we defined unique types of sequences, so called haplotypes. Individual haplotypes are characterised by mutations at defined positions and serve as a basis for all subsequent analyses.

Minimum Spanning Trees

The relationship or genetic distance among haplotypes is shown in a Minimum Spanning Tree (MST, PRIM 1957) (figures 158 and 160). Minimum Spanning Trees or Minimum Spanning Networks are useful to represent all occurring haplotypes and their connections.

The tree's construction is based on a matrix of most parsimonious connections – the smallest number of mutations – between all haplotypes found (SCHNEIDER et al. 2000). In contrast to phylogenetic trees, the haplotypes not only represent the tips of the tree but also the nodes. Each line in the network connects two haplotypes that differ by one mutation. Those haplotypes not found in the sample but necessary for the completion of the tree are added as hypothetic haplotypes. Occasionally, different ways are possible to derive one haplotype from another that require the same number of mutations. This results in loops in the tree and turns it into a network.

Standard indices

To compare the colonies examined, we calculated the three standard indices 'relative abundance of haplotypes', 'haplotype diversity' and 'nucleotide diversity'. The relative abundance of haplotypes describes how frequently a haplotype occurs in one colony compared to its occurance within all colonies sampled. The haplotype diversity (hd) is a measure for the genetic heterogeneity within single colonies and is defined as the proportion of haplotypes that are expected to be polymorphic. Nucleotide diversity (nd) describes the average, relative genetic distance between single haplotypes (TAJIMA 1983). In contrast to the haplotype diversity it not only considers the frequency of haplotypes but also the average proportion of nucleotide differences between all possible pairs of sequences in the sample. Ultimately, nucleotide diversity represents the probability that for two haplotypes chosen at random, two homologeous nucleotides (bases at the same position in the sequence) are different, and is calculated as the average difference between all pairs of haplotypes possible within one sample.

Genetic distances within colonies

Genetic distances between nursery colonies were obtained by pairwise comparisons between single colonies under the assumption of undisturbed gene flow and no differentiation between colonies.

Based on the identified haplotypes in each colony and their frequencies, i.e. the allele frequency (see chapter 8.2.2.), we estimated the genetic variation within and among colonies based on pairwise comparisons. Results are expressed in terms of the fixation index (F_{ST}-index), based on the F-statistics of WRIGHT (1965), which is obtained by permutation of single haplotypes within and among populations (WEIR & COCKERHAM 1984). The F_{ST}-index has a theoretical minimum of 0 (indicating no genetic divergence) and a theoretical maximum of 1 (indicating fixation of alternative alleles in different sub-populations) and provides information about the level of genetic differentiation between two populations (or colonies).

Significance of pairwise F_{ST}-values was tested by calculating the proportion of 1,000 permutations that resulted in an equal or greater F_{ST}-value with the null hypothesis being no difference between populations (i.e. $F_{ST} = 0$).

Analysis of population structure

The partitioning of sequence variation between colonies and among different geographical groupings of colonies was assessed using an analysis of molecular variance AMOVA (EXCOFFIER et al. 1992, WEIR & COCKERHAM 1984). As with F_{ST}-values, this estimation procedure is based on the above-mentioned F-statistics developed by WRIGHT (1965) for the calculation of allele correlations. Based on a comparison of sequences, an AMOVA takes into account the frequency of haplotypes and the number of mutations between haplotypes, and estimates the proportion of total variation found within and among all groups defined (e. g. colonies). The resulting F_{ST}-value does not only provide information about differences but also about the extent of the genetic divergence among colonies. F_{ST}-values have the same range, from 0 to 1 as F_{ST}-values. Significance of the AMOVA results was determined according to a nonparametric permutation method described by EXCOFFIER et al. (1992).

Geographical structure

The correlation of geographical and genetic distance was tested using a Mantel-Test, which calculates pairwise comparisons of the colonies' fixation values (F_{ST}-values) and the corresponding geographic linear distances in kilometres (table 35) (MANTEL 1967, SCHNEIDER et al. 2000, SMOUSE et al. 1986).

8.4 Results

8.4.1 Serotine bat

We analysed a total of 109 individuals from the six nursery colonies of serotine bats known in the study area. Sequencing a 246 base-pair long segment of the mitochondrial control region revealed 16 variable positions defining a total of 18 haplotypes (see table 33). Depending on the absolute frequencies of the haplotypes, common, rare and private haplotypes can be distinguished. Private haplotypes are those that only occur within one colony.

For the colonies sampled we found the following frequency distribution: two common haplotypes with at least one of them occurring in every colony, four rare haplotypes that were found in two to three colonies and twelve private haplotypes that were present in four of the six colonies sampled. Lineage relationships of the haplotypes found are shown in figure 158.

Table 33: All occurring haplotypes in the nursery colonies of the serotine bat and the number of animals sampled (n) in each of the colonies. Private haplotypes are shown in bold letters.

	Haplotype																		n
	h1	**h2**	**h3**	h4	h5	**h6**	**h7**	**h8**	h9	**h10**	**h11**	**h12**	h13	**h14**	**h15**	**h16**	h17	**h18**	
Eckelshausen	5	3	2	3	2	1	1	1											18
Großseelheim	10				1				7	1	1	1							21
Kirchhain	2								3				13						18
Marburg	5			1					3				3	1	1	1	4		19
Mardorf	1			2					16								1	1	21
Wittelsberg	2								9								1		12
frequency	25	3	2	6	3	1	1	1	38	1	1	1	16	1	1	1	6	1	∑109

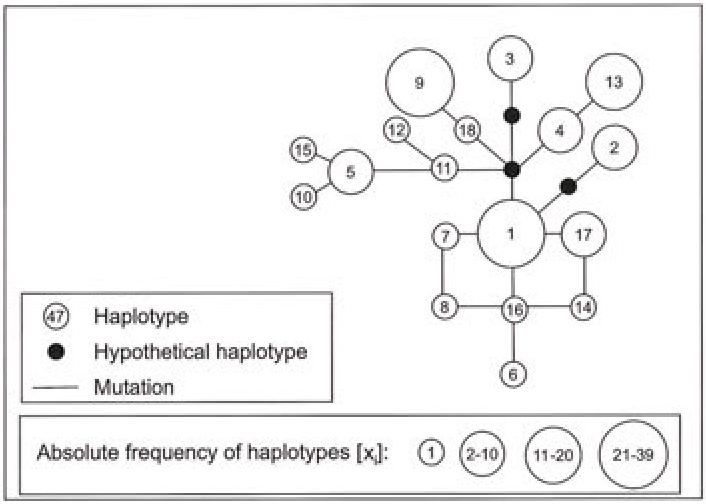

Figure 158: Lineage relationships between the 18 haplotypes found in the serotine bats. Each circle (abundance indicated by size) represents an existing haplotype. Black dots represent hypothetical haplotypes and every line connecting two haplotypes represents one mutational step. The haplotypes are rather closely related as indicated by the compact shape of the minimum spanning network. The two most abundant haplotypes are haplotypes 1 and 9.

Distribution of the haplotypes showed a heterogeneous pattern throughout the colonies, independent of the sample size for individual colonies. A minimum of three and a maximum of eight different haplotypes were found within single colonies. The central haplotype of the minimum spanning tree (figure 158), haplotype 1, occurred in all six colonies sampled and was the most common haplotype in the colonies of Eckelshausen, Marburg and Großseelheim. The overall most common haplotype, haplotype 9, was found in all but the most distant colony in Eckelshausen. The highest agreement in terms of haplotype composition was found for the colonies Wittelsberg and Mardorf. From a total of five haplotypes found, three had similar frequencies. Considering the distribution of private haplotypes, the most distant colony Eckelshausen was also the most differentiated, exhibiting five private haplotypes.

The quantitative results calculated for the colonies are in concordance with the qualitative results described (table 34). Haplotype diversity was proportionally related to nucleotide diversity, because all of the haplotypes found within single colonies differed by five mutations at most and therefore were very similar to each other. As expected, values were highest for Marburg and Eckelshausen as these colonies were the most diverse of the six colonies.

Table 34: Sample size (n), number of haplotypes (# ht), haplotype (hd)- and nucleotide diversity (nd) of the serotine bat colonies sampled.

Colony	n	# ht	hd	nd [%]
Eckelshausen	18	8	0,88	1,1
Marburg	19	8	0,87	1,0
Mardorf	21	5	0,42	0,5
Wittelsberg	12	3	0,44	0,5
Großseelheim	21	6	0,69	0,9
Kirchhain	18	3	0,46	0,7

A comparison of the genetic variance within and among all colonies was carried out using an AMOVA (Analysis of Molecular Variance), yielding a F_{ST}-value of 0.285 that differed significantly from zero. This means that 28.5 % of the total genetic variance can be explained by differences among colonies and 71.5 % of the variance is attributable to variation within colonies. Pairwise F_{st}-values, calculated based on the haplotypes and their frequencies in the colonies, differed considerably (table 35). The largest difference found among colonies was 54 % ($F_{st} = 0.54$), i.e. half of the overall variance of these two colonies was due to differences between them. The smallest difference of 4 % was found for the pairwise comparison of Eckelshausen and Marburg ($F_{st} = 0.04$).

We found no correlation of genetic distances and linear geographic distances among colonies, as shown in figure 159.

Table 35: Matrix of the genetic distances (as pairwise F_{st}-values) and the geographic distances among colonies (as linear distances [km]). Significant values ($p < 0.05$) are shown in bold.

	Eckelshausen	Marburg	Mardorf	Wittelsberg	Großseelheim	Kirchhain
Eckelshausen		18.5	29.5	26.0	23.5	27.5
Marburg	**0.04**		11.0	8.0	6.5	11.0
Mardorf	**0.42**	**0.35**		4.5	7.0	6.5
Wittelsberg	0.33	**0.26**	0.04		6.5	8.5
Großseelheim	0.07	0.05	**0.25**	0.15		4.5
Kirchhain	**0.34**	**0.29**	**0.54**	**0.51**	**0.38**	

8.4.2 Common pipistrelle

We analysed a total of 191 pipistrelle bats from 11 nursery colonies (see table 36 and figure 157). The sequencing of 223 base pairs of the hypervariable domain II revealed 41 variable positions, defining a total 38 haplotypes. The most parsimonious connection among all 38 haplotypes by mutational events resulted in a minimum spanning tree (MST) with three distinct clades, representing older matrilineages (see table 36 and figure 160). Haplotypes of all three clades were found in most colonies. The exceptions were the three colonies in the

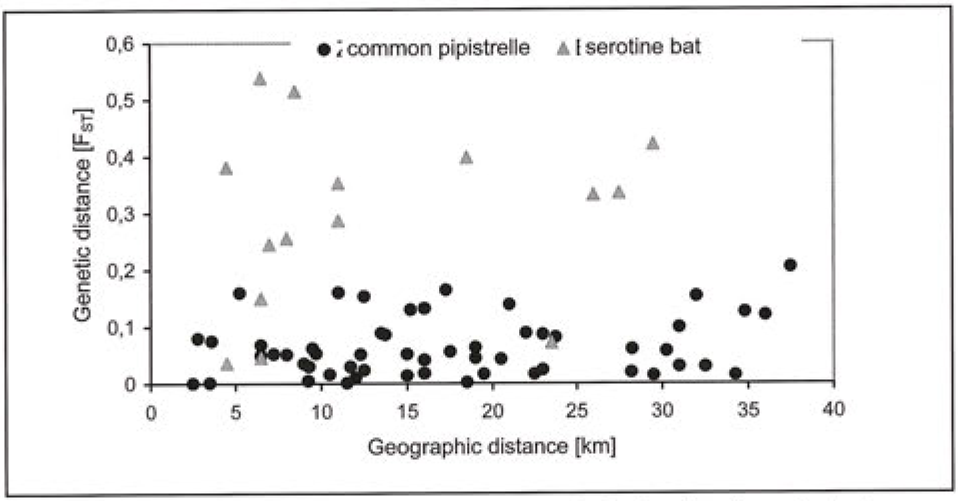

Figure 159: Genetic distance (pairwise F_{ST}-values) among colonies plotted against pairwise linear geographic distances.

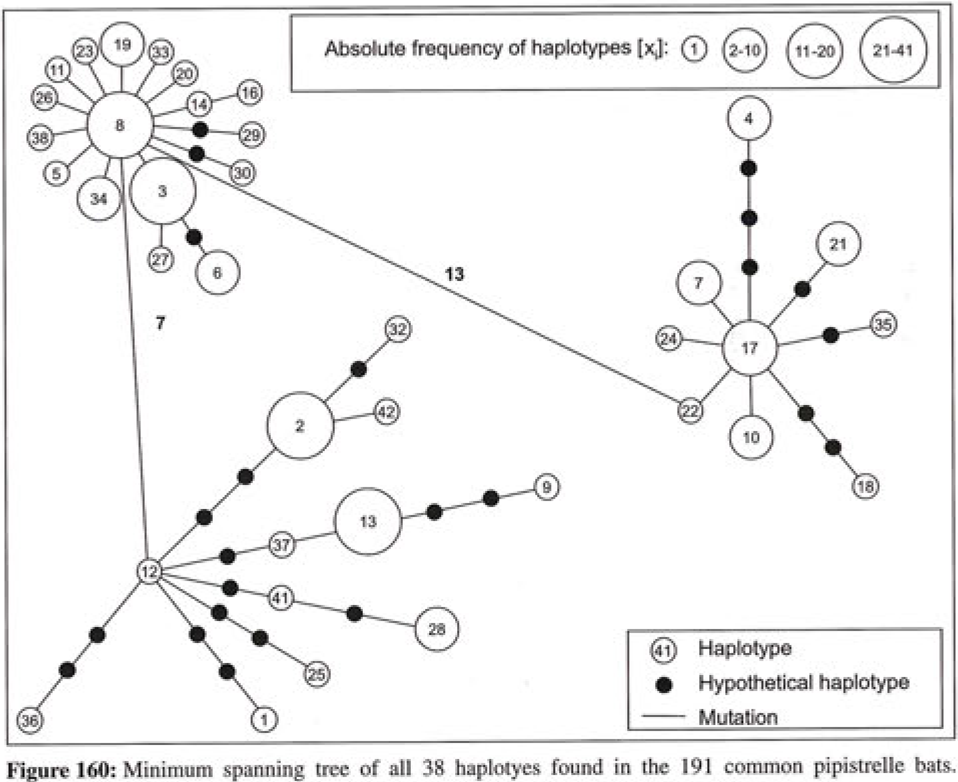

Figure 160: Minimum spanning tree of all 38 haplotyes found in the 191 common pipistrelle bats. Haplotypes form three clades, presumably representing older matrilineages.

Table 36: Common pipistrelle colonies (abbreviated with the first three letters), their composition of haplotypes, and the number of individuals analysed. Common haplotypes are printed in bold letters.

	h01	**h02**	**h03**	h04	h05	h06	h07	**h08**	h09-h12	**h13**	h14	h16	**h17**	h18	h19	h20	h21-h26	h27	h28	h29	h30	h32	h33	h34	h35	h36	h37	h38	h41	h42	n
Bie		**7**	**4**					**2**		**5**			**1**						2												21
Cal		**7**	**4**			1		**3**		**1**			**2**	1	1	1															21
Dex		**1**	**5**			1		**5**		**1**			**3**											1					1	1	19
Der		**5**				2		**3**					**1**		2							1	1								15
Eck		**1**	**2**							**3**														2	1	1	1				11
Gön		**1**	**12**					**1**		**7**	1																				22
Loh		**3**						**5**					**3**				1each											1			18
Mar	1	**5**	**2**	2	1	1	1	**1**	1each			1																			19
Obe			**4**					**1**		**6**																					11
Quo			**2**					**1**		**7**								1													11
Sch		**11**						**3**		**1**			**4**						1	1	1						1				23
	1	**41**	**35**	2	1	5	1	**25**		**31**	1	1	**14**	1	3	1		1	3	1	1	1	1	3	1	1	2	1	1	1	191

western part of the study area, Gönnern, Obereisenhausen and Quotshausen, in which only haplotypes of two of the clades were found.

Individual haplotypes differed in their geographical distribution. The four most common haplotypes (h2, h3, h8, and h17) were widespread throughout the main study area, and were found between 14 and 41 times. Twenty-eight haplotypes were found at one site only, with numbers ranging from two to five. Nine of the 11 colonies had private haplotypes (between one and six), with no haplotype occurring more often than twice.

Quantative results, i.e. haplotype diversity and nucleotide diversity, are shown in table 37. Striking are the high haplotype diversity values found in the nursery colonies of the pipistrelle bat that mirror the high number of different haplotypes found within single colonies. The number of haplotypes observed in a single sampling locality ranged from 3 to 12. The colony with the lowest number of different haplotypes (Obereisenhausen) also showed a low haplotype diversity. Similarly low values are found in the neighbouring colonies Quotshausen and Gönnern, that are located only two to three kilometers apart (table 38).

Table 37: Sample size (n), number of haplotypes (# ht), haplotype (hd)- and nucleotide diversity (nd) of the common pipistrelle´s colonies sampled.

	n	# ht	hd	nd [%]
Biedenkopf	21	6	0.8	3.1
Caldern	21	9	0.9	4.0
Dexbach	22	9	0.8	3.4
Dreihausen	15	7	0.9	3.8
Eckelshausen	11	7	0.9	3.6
Gönnern	22	5	0.6	2.3
Lohra	18	10	0.9	4.7
Marburg	19	13	0.9	4.9
Obereisenhausen	11	3	0.6	2.4
Quotshausen	11	4	0.6	2.3
Schweinsberg	23	8	0.7	4.0

Table 38: Pairwise geographic (linear distances in km) and genetic distances (F_{st}-values) among nursery colonies of the common pipistrelle. Values differing significantly from zero ($p < 0.05$) are shown in bold.

	Bie	Cal	Dex	Dre	Eck	Gön	Loh	Mar	Obe	Quo	Sch
Biedenkopf		11.7	5.3	31.0	3.5	11.0	21.0	20.5	9.5	8.0	34.3
Caldern	0.03		11.5	19.0	9.3	15.0	12.0	9.3	12.3	13.5	23.0
Dexbach	**0.20**	0.02		29.5	6.5	16.0	22.5	19.5	13.8	12.5	32.0
Dreibach	0.03	0.04	0.03		28.2	30.3	16.0	10.5	28.3	31.0	9.0
Eckelshausen	0.00	0.00	**0.09**	0.02		9.7	17.5	18.5	7.3	6.5	32.5
Gönnern	**0.16**	0.05	0.03	0.06	0.05		16.0	23.0	2.5	3.6	37.5
Lohra	**0.14**	0.01	0.03	0.04	0.06	**0.13**		12.5	15.2	17.3	23.8
Marburg	0.04	0.03	0.04	0.02	0.00	**0.09**	0.02		19.0	22.0	15.0
Obereisenhausen	0.06	0.05	**0.11**	0.06	0.05	0.00	**0.13**	0.06		2.8	34.8
Quotshausen	0.05	0.09	**0.18**	0.10	0.05	0.08	**0.16**	0.09	0.08		36.0
Schweinsberg	0.01	0.02	**0.19**	0.04	0.03	**0.20**	0.08	0.01	**0.13**	**0.12**	

The AMOVA performed for all colonies resulted in a F_{ST}-value of 0.063, meaning that differentiation among colonies explains 6.3 % of the total variation and that consequently 93.7 % of the genetic variation is found within colonies.

Computation of pairwise F_{ST}-values, based on the haplotypes and their frequencies, yielded values from 0 to 0.2, with only 14 significant values, ranging from 0.11 to 0.20, out of a total 55 comparisons (table 38). The maximum differentiation between two colonies was therefore about 20 %. Noticeably, all of the pairwise values were lower than 0.3 and the mantel test showed no correlation between genetic and geographic distances among colonies (figure 159).

8.5 Discussion

Knowledge of the genetic structure of nursery colonies allows inferences to be drawn about the composition of colonies and the migration behaviour of the females.

Natal philopatry of female offspring results in the accumulation of the same or closely related and therefore very similar haplotypes and thus in the occurrence of maternal lineages (chapter 8.2.1) within colonies (AVISE et al. 1987). Even though bats are highly mobile they show, to various degrees, genetic structure among colonies. Such structuring usually only occurs with a certain amount of isolation between colonies, either geographical or caused by social structure (WRIGHT 1965). Natal philopatry is most likely apparent in several European bat species, as shown in studies that used direct and/or indirect methods (BURLAND et al. 1999, CASTELLA et al. 2001, ENTWISTLE et al. 2000, HEISE 1989, HEISE & SCHMIDT 1988, KERTH & KÖNIG 1999, PETIT et al. 1999, PETRI et al. 1997).

Results from our mark-recapture studies support the genetic results in that evidence for natal philopatry was found for both species, the pipistrelle and the serotine bat. However, it was not possible to quantify the extent of site fidelity. Even though female natal philopatry is probably the norm, the number of females migrating to other colonies can be quite variable. Such migration events, especially if they are rare occasions, are especially difficult to detect – if at all – with direct methods (e. g. mark and recapture).

Although the colonies of both species studied genetically were located within a relatively small area, nursery colonies of the common pipistrelle showed a relatively high sequence divergence of 18 %. The serotine bat showed a clearly lower divergence of about 6.5 %. Compared to the greater mouse-eared bat *(Myotis myotis)* (CASTELLA et al. 2001), haplotype diversity in the pipistrelle is twice as high and rivals values found for nursery colonies of the noctule bat *Nyctalus noctula* throughout Europe (PETIT 1998).

If female offspring would strictly return to their natal colony, one or few haplotypes would rise to dominance over time. This was clearly not the case for both species. Although single haplotypes were found with up to 12 respectively 13 copies within single colonies, haplotype diversities were as high as 0.6 and 0.9 for the colonies of the pipistrelle, and slightly lower for the colonies of the serotine bat. Comparably high values were found for the noctule bat (hd = 0-0,96 [PETIT & MAYER 2000]) and the greater mouse-eared bat (hd = 0,1-0,76 [CASTELLA et al. 2001]).

The mitochondrial haplotypes found in the common pipistrelle showed a grouping into three clades, something not found in the serotine bat. Those clades or groups of haplotypes differed on average about 6.5 % or by about 14.5 base substitutions (figure 158 und figure 160). Such deep splits are usually caused by long periods of geographic isolation and thus limited gene flow. A likely scenario is that the three groups evolved during the ice ages (AVISE 1989; AVISE 1994, WILKINSON & FLEMING 1996). Three clades were also found in studies of the two above-mentioned bat species, the noctule bat (PETIT et al. 1999) and the greater mouse-eared bat (CASTELLA et al. 2001) and it seems conceivable that these species used the same ice age refugia. In contrast to the other two species, in which only one clade shows considerable diversification (CASTELLA et al. 2001, PETIT & MAYER 2000), all three clades of the common pipistrelle consist of several haplotypes (figure 160).

In the pipistrelle, haplotypes of all three clades were found across the colonies studied. This pattern of co-occurring clades that suggests lack of geographic structure was also found in a study of mass hibernacula throughout Germany (HÜTTENBÜGEL et al., in preparation).

The high divergence of haplotypes in pipistrelle bats was reflected in a high nucleotide diversity of 2–5 %. In the serotine bat, where all haplotypes were closely related, values for nucleotide diversity only ranged from 0.5 to 1.0 %.

Clear differences between the two species became apparent when comparing the distribution of the overall genetic variation among the colonies, Colonies of the common pipistrelle were very genetically diverse and therefore only a small part of the overall variation (6.3 %) could be explained by differences among colonies. This value is extremely low compared to the serotine bat. Colonies of the serotine bat had fewer haplotypes, and therefore had less diverse colonies and about 28.5 % of the overall found divergence can be explained by differences among colonies. This clearly demonstrates that colonies of the common pipistrelle are much more heterogeneous but there is a lower variance among colonies, suggesting a higher exchange of animals.

In a population genetics study of the Bechstein's bat *(Myotis bechsteinii)* by KERTH et al. (2000) the variance among colonies was even higher than our results presented for the serotine bat: 68 % of the overall genetic variance in Bechstein's bats could be explained by differences among colonies indicating an extremely low rate of exchange among colonies.

The evaluation of gene flow via direct methods gets even more complicated because not every animal that changed to another colony will become resident and more importantly breed in the new colony. Using indirect methods gives the opportunity to calculate a migration coefficent based on the spatial distribution of genetic variation (F_{ST}-values) (HARTL & CLARK 1997, SLATKIN 1987). This coefficient describes the proportion of alleles belonging to one population that will be gained through migration. The exchange of one individual within one generation can be considered as an approximate threshold for prevention of strong genetic differentiation. According to TAKAHATA & PALUMBI (1985), in haploid systems (e. g. mitochondrial DNA) F_{st}-values less than 0.3 indicate levels of gene flow that prevent strong genetic differentiation. Even though this model is not very precise (WHITLOCK & MCCAULEY 1999), it can be used as a rough guideline. Most of the pairwise F_{st}-values (10 out of 15) among colonies of the serotine bat were above this threshold of 0.3, with a minimal variance among colonies of 4 % ($F_{st} = 0.04$) and a maximal variance of 54 % ($F_{st} = 0.54$). Therefore it is most likely that even though the colonies are located close to each other, the exchange of females is not high enough to prevent genetic differentiation. In contrast, common pipistrelle nurseries are much less differentiated, suggesting higher gene flow than in serotine bats.

Colonies sizes of the pipistrelle as well as those of the serotine bat are probably too small to prevent the effects of genetic drift. Instead it is likely that the exchange of females plays an important role in maintaining genetic diversity. Consistent with the genetic results, band-recapture data for colonies of the common pipistrelle revealed even a high rate of exchange among more distant colonies (chapter 7.2.1 und chapter 7.4.1, FEYERABEND & SIMON 1998). No such recaptures could be documented for the serotine bat despite intense capturing efforts. Nursery colonies of the latter species seem to have similarly low exchange rates as those described for the brown long-eared bat (*Plecotus auritus*) and the Bechstein's bat (ENTWISTLE et al. 2000, BURLAND et al. 2001, ROSSITER et al. 2000, KERTH et al. 2002). Nevertheless, unless there was at least some genetic exchange among colonies of the serotine bat, colonies would show even more differentiation. Results from telemetry conducted in the project showed spatial overlap in the homeranges of nursery colonies from neighbouring villages. We did find for example that animals from different colonies used the same hunting area or that single females roosted solitarily in villages without another colony of the same species. These observations illustrate the possibility of gene flow as indicated by the genetic results. There was no increase in genetic variation relative to geographic distance among colonies for the two species, thus indicating the existence of ongoing exchange of females up to linear distances of 40 km in common pipistrelles and about 30 km in serotine bats. This is comparable to results for nursery colonies of the common brown long-eared bat *(Plecotus auritus)*, that show no significant signs of isolation by linear distances up to 40 km. Significant isolation by distance was only found for distances of about 100 km or greater (BURLAND et al.1999).

In general, this would imply that the exchange usually does not happen over the maximum distance but more in a stepping-stone-like fashion. A nursery colony of the serotine bat, not part of the genetic investigation because it was discovered too late in the project, located between the most distant colony in Eckelshausen and the other colonies, is a colony that could be such a stepping-stone.

Implications of genetic results for the protection of roosts

The results of the genetic studies of the two house-dwelling bat species common pipistrelle and serotine bat reveal differences as well as similarities between them. A correlation of genetic variation and geographic distance was not detected within the study area, either for the eleven colonies of the pipistrelle, or for the six colonies of the serotine bat. For the serotine bat, this provided evidence of genetic exchange among colonies that could not be documented by mark/recapture. However, exchange rates in the serotine bat are much lower than for colonies of the common pipistrelle. This results in recommendations for the protection and management of the two species.

The stronger tendency towards female natal philoaptry in serotine bats is likely to diminish the probability of colonising new villages. That is why this species – as well as probably other species with limited distribution – are in need of protection in their entire groups of colonies.

In areas where this species is uncommon or rare, specific attention should be given to the protection of existing colonies. Low levels of individual exchange combined with low population sizes could easily lead to increased isolation among colonies and result in elevated local extinction risk. Increasing the number of available colony roosts is therefore especially important for the serotine bat. Thereby it should be taken into account that connectivity among colonies appears to be particularly important on small spatial scales, i.e. within the same village (see chapter 7.2.2). Creation of new, potential colony roosts should also include villages inbetween existing colonies that are separated by larger distances. This would create potential stepping-stones providing increased opportunities for connectivity and exchange of individuals among colonies.

The situation is different for the common pipistrelle, for which colonies exhibit only low levels of genetic differentiation suggesting higher levels of gene flow. A specific program for the creation of new colony sites is probably not warranted for this species, especially in areas where it occurs in high densities.

8.6 Summary

- Sequence divergence in mitochondrial DNA of the common pipistrelle was relatively high (18 %) compared to the serotine bat (6.5 %).
- Although up to 13 copies of a haplotype could be found in the same colony, haplotype diversities were as high as 0.9 for the common pipistrelle, and only slightly lower for colonies of the serotine bat.
- Colonies of the common pipistrelle are genetically very diverse; consequently only a small part of the overall variation (6.3 %) can be explained by differences among colonies. This value is extremely low compared to that found in the serotine bat (28.5 %) and suggests that common pipistrelle colonies experience a more common exchange of individuals.
- Pairwise F_{st}-values for serotine bat nurseries indicate a much lower exchange rate of females among colonies compared to those of the common pipistrelle.
- Genetic variation did not increase with geographic distance among colonies for either of the two species, indicating regular exchange of females up to linear distances of 30 km to 40 km.

Our results indicate that nursery colonies of the serotine bat are more prone to isolation effects than colonies of the common pipistrelle. Therefore, the former species and other bat species with a similarly patchy distribution are especially dependent on the protection of existing nursery roosts and the establishment of new roosts. Once local extinction from a village has occurred for the serotine bat, recolonization of that village in the near future seems unlikely.

9 Roost destruction

9.1 Introduction

Bats use numerous roosts of different kinds in and on buildings (see chapter 5). Human building construction activity once gave the bats a rich spectrum of hiding places. The aging of building substance gives new hiding places for a certain period of time until it reaches a point where the state of dilapidation is too bad and thus the roosts are uninhabitable (e. g. because of drafts, dampness, entry of martens). There are many other causes of a reduction in roosting opportunities in buildings. Among the numerous general danger caused by humans, KLAWITTER (1986) and RICHARZ (1993) name some that have a great importance for house-dwelling bats regarding their roosts. They are summarised and expanded below.

The main causes for loss and impairment of roosting opportunities are:

- Re-development of buildings and the pulling-down of old houses which lead to a closing of crevices and holes or total destruction of the roosts;
- Renewal of roofs containing roosts, especially during the nursery period which may lead to massive disturbances (expulsion) and even the death of numerous young animals;
- Adding extensions to the top of the house or converting an "empty" attic into living quarters;
- Extensive restauration programs such as the restauration of town-centres or villages;
- New buildings in modern architectural style with smooth walls, good heat insulation, and self-contained rooms; and
- Use of timber preservatives (e. g. roof timberwork impregnation), which poisons bats.

Concepts to preserve bat roosts in buildings have already been drawn up several times in Germany and Central Europe. The latest one by DIETZ & WEBER (2002) gives comprehensive insight into this topic.

However, data concerning roost destruction useful for evaluation can rarely be found in the literature, they are usually individual examples. From Indiana (USA) it is reported that within 30 years half of all occupied roosts have been destroyed (see COPE et al. 1991). A study from England shows a destruction of 70 % of *Pipistrellus pipistrellus* known roosts within a 15-year period (1978 to 1993) (ANON. 1995).

9.2 Roost destruction in the project area

The destruction of bat roosts is to a larger degree not to be attributed to intentional extermination, but probably results predominantly from necessary, regular renovations of buildings (for an example of roost preservation see figure 161).

A great number of roosts have to be observed, if at all possible, to show accurately the quantity of regular roosts destruction. This can be realised at best with the roosts of the common pipistrelle, which is quantitatively found most often. The type of crevice roosts the common pipistrelle bat uses corresponds with those of other house-dwelling species (e. g. serotine bat, whiskered bat), so that the results of roost destruction can be transferred to these species. In order to obtain a precise rate of destruction, known maternity roosts of the **common pipistrelle** were examined once and then again after an interval of some years. A total 125 roosts were chosen to provide the basic data (see figure 162) and their condition recorded in two checks. The first check took place in the first year of project 1997 and covered 26 roosts, which had already been registered from 1990 to 1996 in unpublished reports as well as voluntary surveys (emphasis of registration 1991–1993). During the second check in 2001, 99

Figure 161: Maternity roost of the common pipistrelle, which could be preserved from destruction within the framework of the project (view from below onto roof case, arrow = entrance gap).

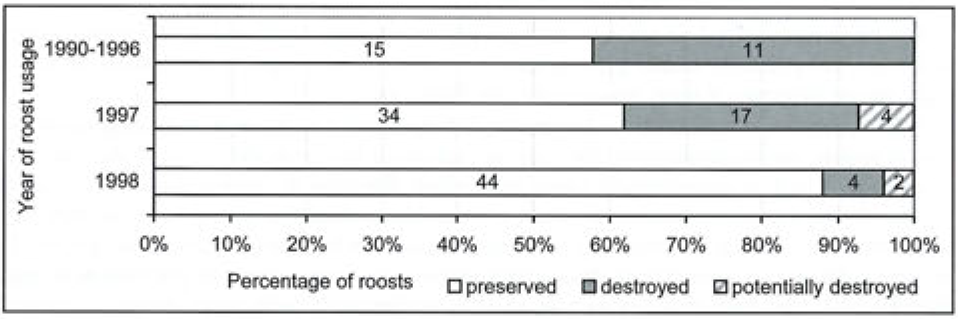

Figure 162: Three "year groups" of maternity roosts of the common pipistrelle (n = 125), which were checked for roost destruction. Percentual portion of destroyed roosts is grey (n = 32). The potentially destroyed roosts result from the assumption that for each group of roosts five years had passed until observation.

roosts were examined which had been chosen randomly from all roosts found in 1997 and 1998. Consequently, the intervals of checking were not uniform. The "1990–1996 group" was checked after 1 to 7 years (an approximate average of 5 years is supposed), the "1997 group" after 4 years and the "1998 group" after 3 years.

Added to this, the age of roosts was not known (first times of use was rarely recorded) and the precise time of roost destruction was seldom known, so that for example no "average age of roost" can be calculated.

The observations showed that 32 (25 %) of the 125 roosts checked (see figure 162) had been destroyed. This total refers to the three different "year groups" of roosts. To be able to compare the results better, the "1997 group" and "1998 group" can be projected to a 5-year observation interval by calculating the average of yearly destructions for the years missing (see table 39). With this the number of destroyed roosts of the "1997 group" rises by four and those of the "1998 group" by two (potentially destroyed roosts are hatched in figure 162 and indicated in brackets in table 39). Within 5 years this results in a total of 38 % or 29 %, respectively, of destroyed roosts.

The comparison of annual destruction rates (see table 39) is interesting as the different checks resulted in strikingly varying rates. Whereas the annual destruction rates at first still lay above 8 %, for roosts first recorded in 1998 and checked in 2001 there is clearly a lower rate, namely 2.7 %. This shows a distinct fall in roost destruction. It is possible and likely that public awareness campaigns had a favourable effect on the protection of roosts in manifold ways in the days of the project. The numerous amounts of information and advice given to roost owners – especially during trapping exercises or emergence counts, both of which involved intensive "babysitting" of the roosts – played a large share in many roosts being spared during renovations. Some inquiries made by householders who wanted to be advised during renovation work also illustrates this.

These results on roost destruction are of great importance as they are the first quantative recording of the permanent destruction of bat roosts at buildings. It has to be considered that these roost destruction rates are not connected with any pronounced wave of restauration or rebuilding, as for example has been the case in the eastern states in Germany since 1990, but that they should reflect a "normal rate". It is to be judged as extremely serious that nearly all destructions registered took place with the full knowledge of the householders.

The illustrated projection below has been drawn up to further clarifiy this problem (see figure 163). The individual control round rates for annual destruction were calculated on the basis of the recorded data to take into consideration the differing number of years. From this the average destruction rate can be calculated, namely 6.4 % (which is probably somewhat too low). On the basis of this value it follows that after 15 years already 50 % of all crevice roosts in buildings will have disappeared by measures of renovation or restauration. Figure 163 shows visually how within 30 years, of 28 roosts present in the year 2000 ("normal" size

Table 39: Roost condition registered for 125 randomly selected common pipistrelle roosts (the number of potentially destroyed roosts after 5 years is given in brackets).

Year of registration	Year of control	Preserved roosts	Destroyed roosts	Total	Destruction [%]	Years untill destruction	Annual destrucion rate
1990-1996	1997	15	11	26	42	(1-) 5	8.4%
1997	2001	34	17 (21)	51 (55)	33	4	8.3%
1998	2001	44	4 (6)	48 (50)	8	3	2.7%
Total		93	32 (38)	125 (131)	25.5 (29.0)	4	6.4%

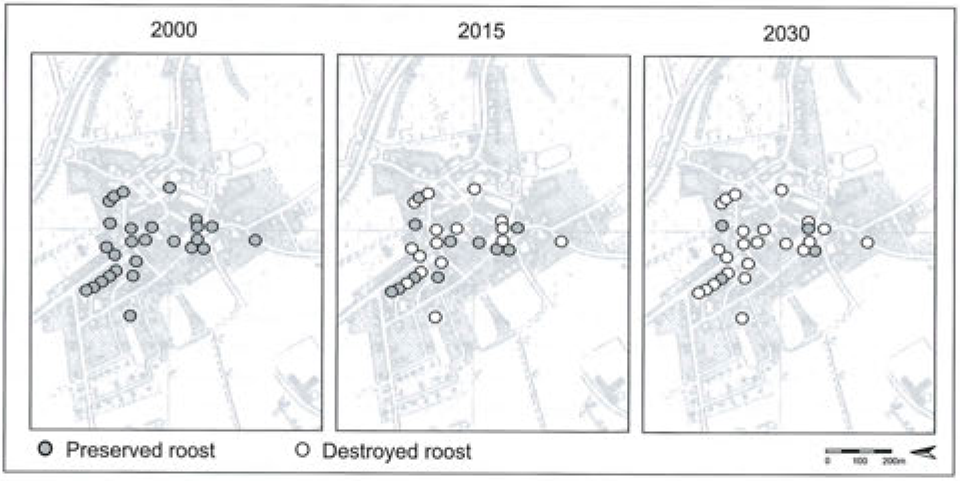

Figure 163: Hypothetical roost destruction within 30 years in the case of an annual destruction rate of 6.4 %. Already after 15 years half of the roosts will have disappeared (calculated by means of destruction rate of common pipistrelle roosts).

of one roost assemblage of common pipistrelles) only four roosts will be preserved in the year 2030.

Concerning the serotine bat there are relatively few data about 29 maternity roosts. Therefore there is little sense in working out a roost destruction rate for this species. All the same, of these 29 roosts which became known during the project, 28 roosts were still intact in 2001. For the most part this was because the roosts of this species were taken care of intensively and thus at least five buildings restaurations / renovations which met the needs of bats could be accomplished (see figure 161, renovations at three other roosts are in planning). Without this supervision, a further five to 8 roosts could have been lost, which is a high rate of loss considering the total number, and is not lower than that of the common pipistrelle.

9.3 Summary

- 29 (25 %) of the 125 common pipistrelle roosts that were checked were destroyed.
- The annual destruction rate of common pipistrelle roosts fell clearly from 8.4 % to 2.7 %. The intensive public awareness campaign within the framework of the project contributed to this.
- If an average annual destruction rate of roosts of 6.4 % were to continue, after 15 years half of all common pipistrelle roosts would be destroyed.
- More than 25 % of the serotine bat roosts in the project area were threatened by building measures during the run-time of the project. At least 5 roosts were saved from destruction. Thus the annual rate of roost destruction could be approximately the same as that of the common pipistrelle roosts.

10 How successful is the creation of new roosting opportunities?

10.1 Introduction

Some species of bats regularly use or even exclusively use roosts in or on buildings. These house-dwelling bats are especially dependent on the preservation of existing roosts and the creation of new roosts in buildings. Living in such close proximity to humans brings numerous conflicts and problems with it. In many cases house renovations are the cause of a loss of roosts (often because of a lack of information on roost-preserving measures or ignorance that bats are present). Exhaustive redevelopment waves have a really dramatic effect (e. g. town-centre restauration), but also "normal" house renovations are threatening. On top of this, these days there are fewer new roosts coming into being than in former times due to the use of modern materials and types of construction (e. g. minimum stress paths in intermediate roofs, better insulation of the complete building, direct closing of gaps with insect-proof meshes). As an alternative to roosting possibilities "naturally" emerging during the construction work or created by the ageing of the structure substance, the project aimed to find out in which way a newly created potential roost must be designed to be accepted by house-dwelling bats. The requirements bats have for their roosts have already been described in the chapter on roost requirements (see chapter 5.11).

Newly developed structures for bats only become "real" roosts if the bats accept the potential roost. A "new roost" is therefore one that is in fact adopted by bats, not just offered.

In the first part of the chapter the different roost establishment methods applied and the schedule thereof are described in brief. In the second part, the results of inspections of the new roosts are introduced and then assessed as to how fast a potential roost is discovered and/or occupied by bats and which type of potential roost is favoured by them.

10.2 Description of roost offer

10.2.1 Schedule of establishment of roost offers: at which point of time were potential roosts habitable for bats?

The number of newly created potential bat roosts completed and able to be inspected in the project is 121. Figure 164 presents a cumulative schedule of potential roost establishment (newly created). The new creation of roosts needed a certain warming-up time corresponding to organizational expenditure and mainly began in 1998. It reached into the year 2000. Thirty-six new potential roosts were completed only after the first quarter of the year 2000 and were too late to be taken into consideration in the inspection program and consequently in the evaluation. A further 37 roost offers were inaccessable for inspection due to their specific construction or where they were erected (such roost offers could sometimes be included in the final inspection at the end of the project).

10.2.2 Differentiation between new creation, optimisation, preservation, and replacement of roosts

Concerning the measures of creating potential new roosts it is of importence to distinguish between the different categories: "truly new construction" of a potential roost (newly created), roost optimisation, preservation, and replacement (table 40). Strictly speaking only those roosts newly established in places that have not been used as roosts before can be seen as newly created in the narrow sense (56 %) (figure 165). The remaining 44 % are mainly roost optimisations (40 %), e. g. erecting crevice boards in attics that often have natural roost-

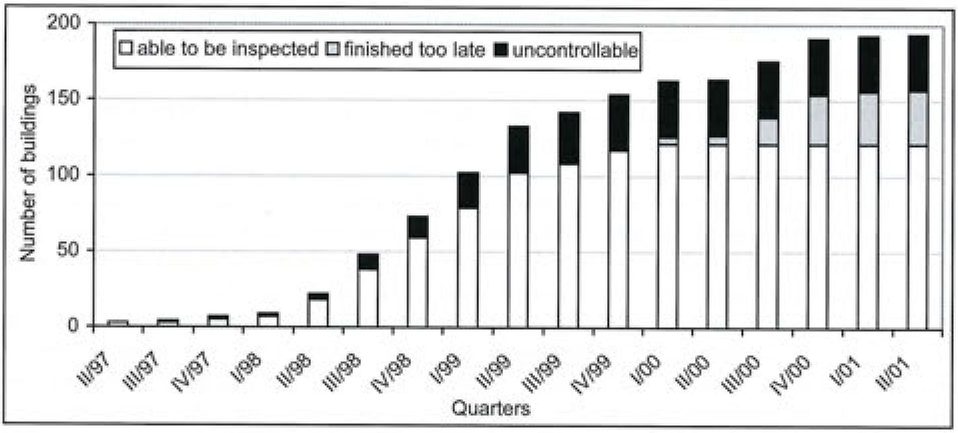

Figure 164: Time schedule (cumulative) for the completion of newly created potential bat roosts within the project (T&D central plan) from mid-1997 until mid-2001. Buildings, whose new roost offer had not been completed by April 2000, are declared as "finished too late" (36 in total).

ing possibilities at their disposal anyway. The remaining 4 % fall into the categories of preservation of existing roosts or replacement of destroyed roosts.

The success of a method, i. e. that the bats discover (and occupy) the roosts offered, is determined by the previous use of the building or attic (= roost location). Thus the evaluation distinguishes between roost offers in buildings "with previous use" and those "without a known previous use", the latter of which are identical with newly created potential roosts.

It is typical that most of the roosting possibilities "with previous use" are in attics of churches (46) and only few are in other buildings (7) (figure 166). The search for traces of bats in church attics resulted in at least a few bat droppings being discovered in more than 80 % of all cases – an indirect proof of use. That means for the evaluation that the roost establishment measures in church attics are optimisations, and these are more likely to be discovered and used by bats.

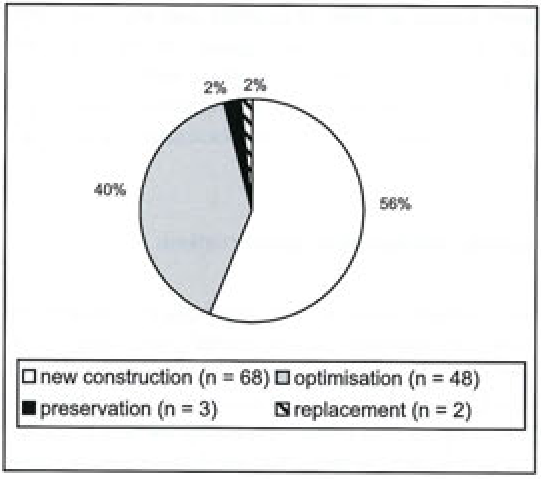

Figure 165: Proportional distribution of the methods for "roost establishment" carried out at 121 buildings; for definitions see table 40.

Table 40: Classification of the different methods applied for "roost establishment".

Method	Description
New construction	Roost establishment at a building without a known previous use by bats
Optimising	Optimising of an existing roost
Preservation	Preservation of an existing roost
Replacement	Establishment of a potential roost replacing a destroyed roost

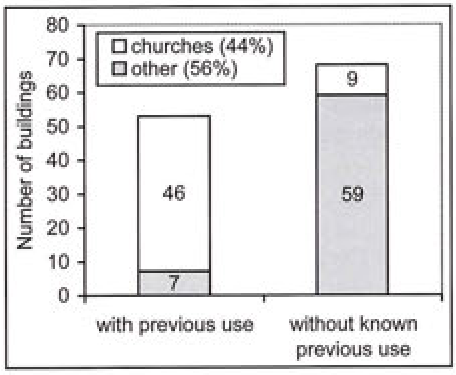

Figure 166:
Number of buildings (n = 121) "with and without a known previous use" by bats, subdivided into churches and other buildings.

10.2.3 Roost types

The different roosting possibilities have been divided into four categories according to their location and the position of the entrance gap (table 41). The different species of house-dwelling bats favour roosts with differing characteristics. Crevice roosts of category I and II, i. e. crevice roosts situated outside or inside with a possibility to fly in from outside, are typical roost types for common pipistrelles and whiskered bats. Long-eared bats and Natterer's bats also use these type of crevices. Roosting possibilities of category III, however, are crevice roosts situated inside with a possibility to fly in from inside. These specifically meet the needs of long-eared bats and sometimes Natterer's bats. An evaluation divided according

Table 41: Four main types of methods undertaken to create potential roosts, differing in the position of the roost and its entrance gap. *Methods in category III sometimes include opening up the attic. This has not been listed separately, as opening up the attic is a prerequisite for the use of crevice roosts.

Category		Building**	Roost offer
I	crevice roosts outside with a possibility to fly in from outside	37	39
II	crevice roosts inside with a possibility to fly in from outside	14	20
III*	crevice roosts inside with a possibility to fly in from inside	80	129
IV	entering possibilities into attics	5	5
			Σ 193

** multiple nominations are possible

to bat species would not be meaningful because of the comparatively small number of roosts, the unequal number of different roost types, and the different frequencies of bat species.

A total 193 roost construction measures were carried out in 121 buildings (figure 167). Only five of these 193 measures are not crevice roosts (categories I–III), but rather the establishment of entering possibilities into attics (table 41). 106 buildings have only potential roosts of one category. Fourteen buildings have roosts of two different categories and only once were roosts of three different categories constructed in one building. For the first step of evaluation, the different roost categories were counted rather than the individual buildings.

Figure 167 shows in which way the roost construction measures were distributed among the buildings. Category III ("crevice roost" inside with entrance from inside) is the measure carried out most often, with 129 roosting possibilities in 80 buildings. Only one individual roosting possibility of this category was constructed in 45 buildings. Of the 35 buildings left, two (25x), three (6x) or four (4x) roosting opportunities were constructed per attic. The ratio of categories I to II is more balanced as mainly single roost construction measures were carried out.

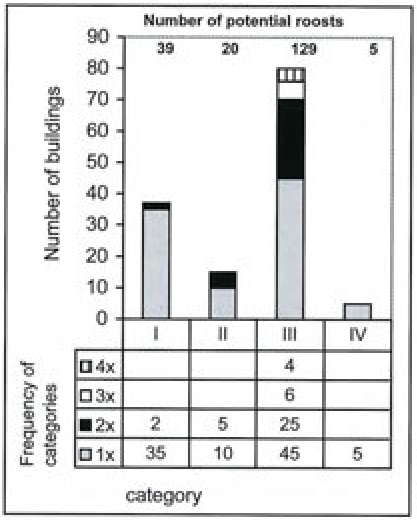

Figure 167:
At 121 buildings, 193 roosting opportunities of 4 categories were established (for categories see table 41).

Individual descriptions of newly created potential bat roosts

Below are detailed examples of 7 roost construction methods of categories I to III. Additionally three examples of entrance possibilities into attics (roost category IV) are presented. More specified descriptions of these roost categories are available in the book "Baubuch Fledermäuse" (Construction for Bats) (DIETZ & WEBER 2000) which assesses potential roosts created within the framework of the project.

10.2.3.1 Gable panneling inside with access from outside (category II)

This "crevice roost" is attached to the inside gable wall whereby the entrance is obtained from outside via a gap (see figure 168). The roost is suitable for crevice-roosting bat species, particularly the common pipistrelle, serotine bat and whiskered bat.

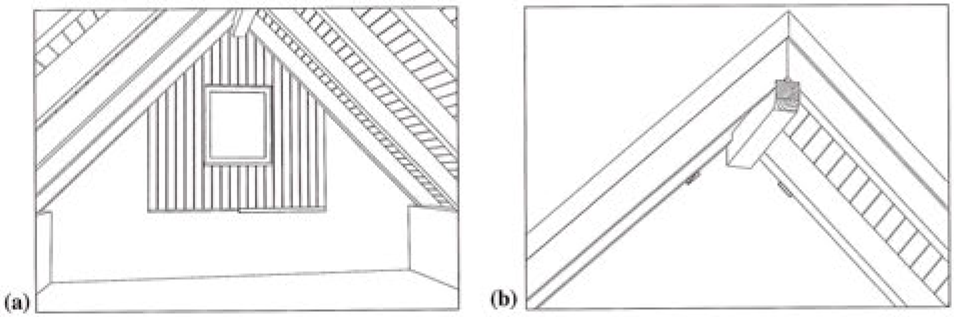

Figure 168: Sketch of "crevice roost" situated inside behind an erected gable panneling (a) with access from outside via two entrance gaps under the protruding ridge beam (b).

This method of roost establishment allows four different possibilities for entrance gaps: under the eaves/gable, on the wall (e. g. bat silhouette), under the window sill or from below on the cladding (e. g. opened/removed insect grilles).

10.2.3.2 Crevice roost under roofing with access from outside (category II)

This crevice roost is established under the roofing between two rafters (see figure 169) and leads directly outside under the eaves where entry is possible (see figure 170). Additionally, a rough landing board is fixed near the entrance gap.

The roost is suitable for crevice-roosting bat species, particularly the common pipistrelle, serotine bat and whiskered bat.

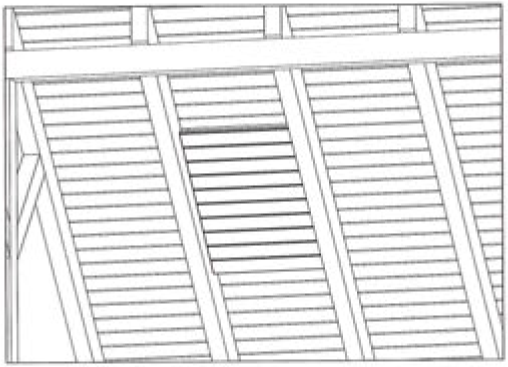

Figure 169: Crevice roost under roofing between two rafters with access from outside.

10.2.3.3 Bat roosting board, single- and double-walled (category I)

The double-walled roosting board for bats consists of rough wood and the bats are able to land on its 10 cm longer rear side (see figures 171, 172 and compare chapter 5.2). If the building's wall is sufficiently rough (roughcast plaster), the wall may also serve as a landing place and backing for the bats when hanging from the board, and therefore a simple board may be sufficient.

The roost is suitable for crevice-roosting bat species, particularly the common pipistrelle, serotine bat and whiskered bat.

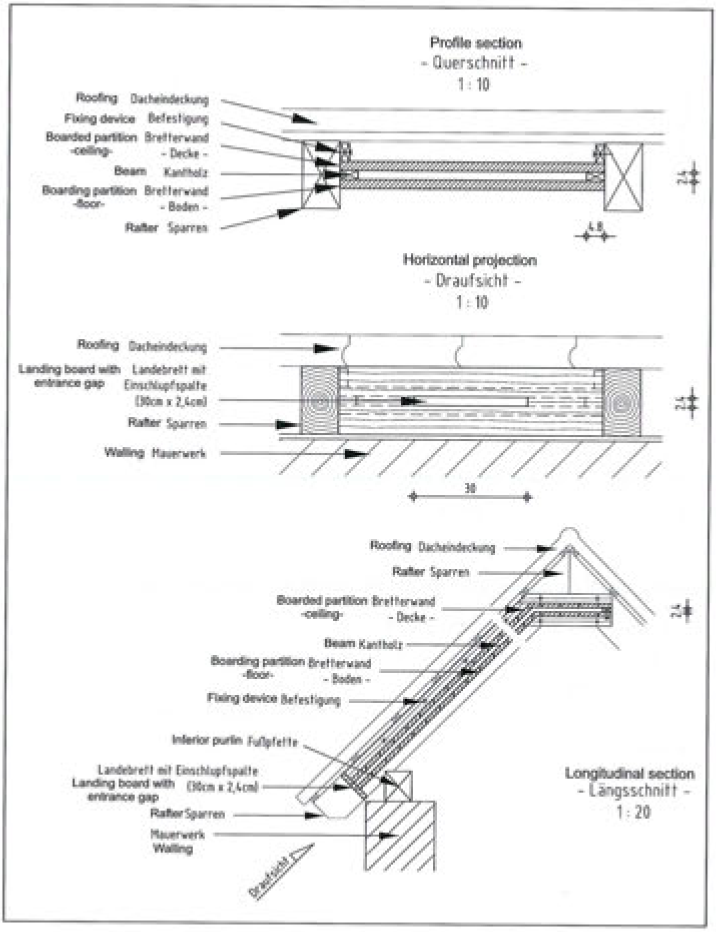

Figure 170:
Sketch of crevice roost under roofing with access from outside in cross-section, horizontal projection and longitudinal section.

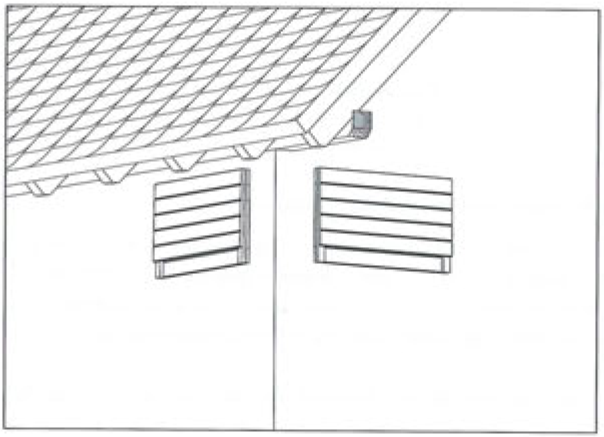

Figure 171:
Double-walled bat roosting boards on two sides of the building.

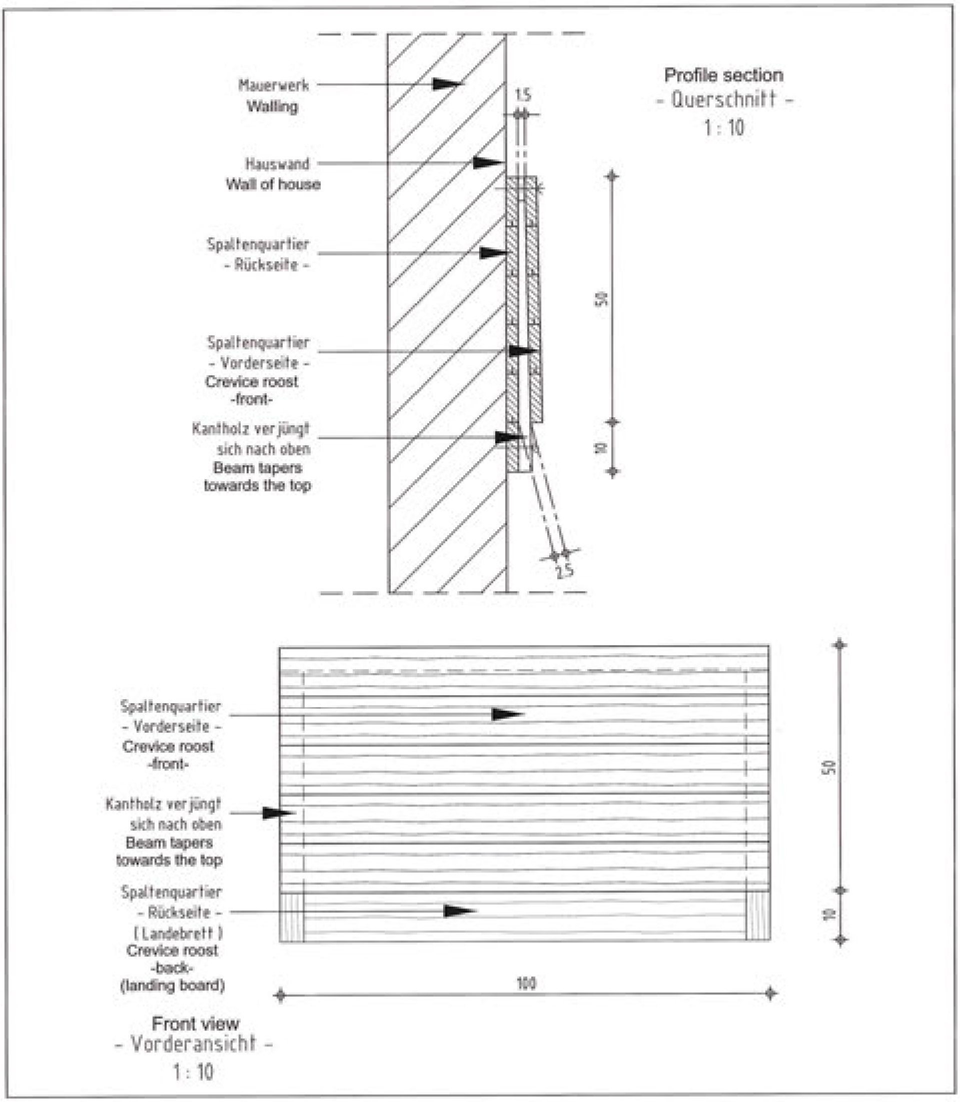

Figure 172: Sketch of double-walled bat roosting boards in profile section and front view.

10.2.3.4 Crevice roost behind ridge beam (category I)

This roost is situated behind the ridge beam which protrudes from the gable wall (see figure 173). There often is a crevice of 1 cm to 2 cm between the ridge beam and the house's wall, which can be used as roost by the bats (see figure 173). In new buildings it can be organised that this crevice be left open and the plastered area reaches only 1.5 cm to 2 cm to the ridge beam (see figure 174).

The roost is suitable for crevice-roosting bat species, particularly the common pipistrelle, serotine bat and whiskered bat.

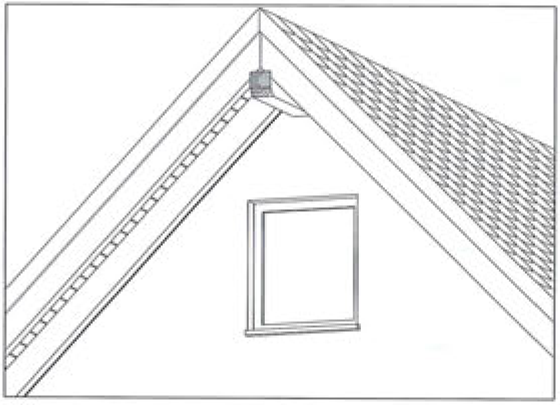

Figure 173:
Crevice roost behind ridge beam at eaves.

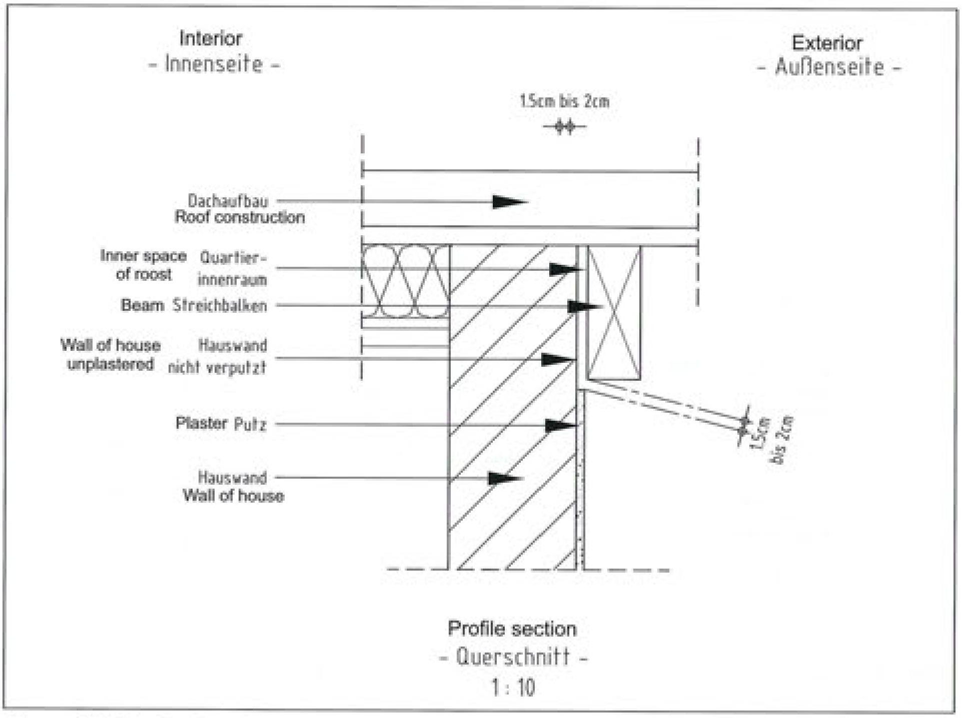

Figure 174: Sketch of crevice roost behind ridge beam (cross-section).

10.2.3.5 Crevice roost behind slate facade (category I)

Bats are able to occupy roosts in cavities between the single slates and between wall's covering boards and the slates or bigger cavities between brickwork and covering boards (see figure 176). This method mainly affects the area between brickwork and covering boards, to which the slate is nailed. Various types of entrance gap can be created on such a facade (see figure 175).

The roost is suitable for crevice-roosting bat species, particularly the common pipistrelle, serotine bat and whiskered bat and in part for long-eared bats and the barbastelle bat.

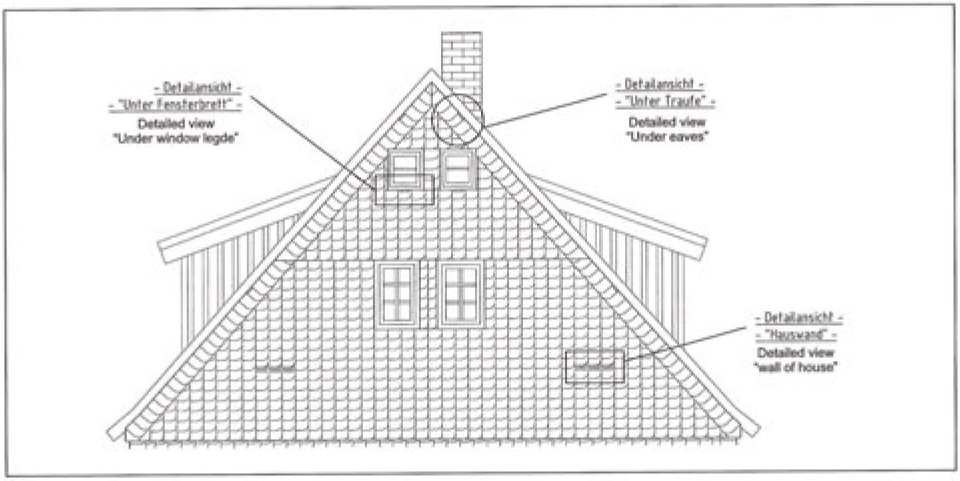

Figure 175: Crevice roost behind slate facade with several entrance possibilities.

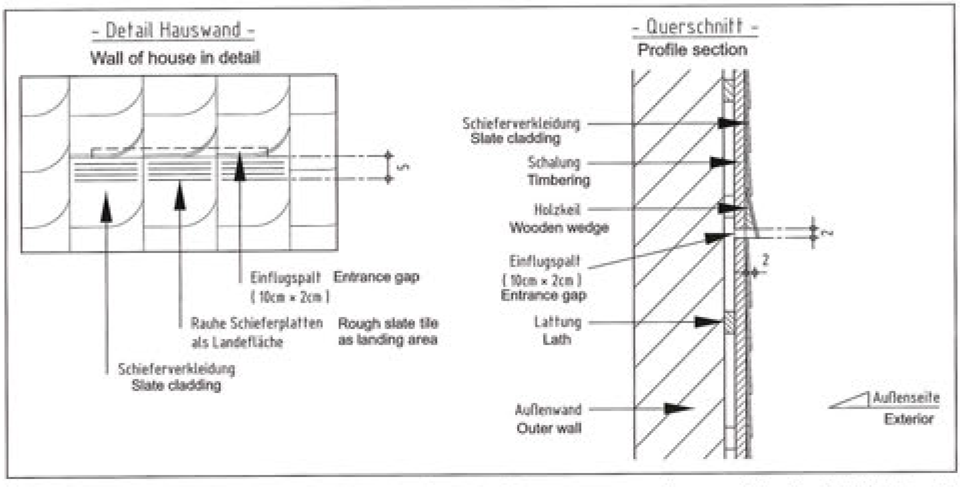

Figure 176: Sketch of crevice roost behind slate facade with an entrance gap integrated into the building's wall.

10.2.3.6 Crevice roosts in attics (category III)

Crevice roosts in attics are constructed in the same way as double-walled bat roosting boards (see figure 178 and compare figure 172). So that they can be erected as high as possible in the ridge, they are triangular or of trapezium shape, corresponding to the shape of the roof (purlin roof or rafter roof) (see figure 177).

This type of roost is suitable for bat species which mainly roost in attics, such as the greater mouse-eared bat, long-eared bats and also Natterer's bat.

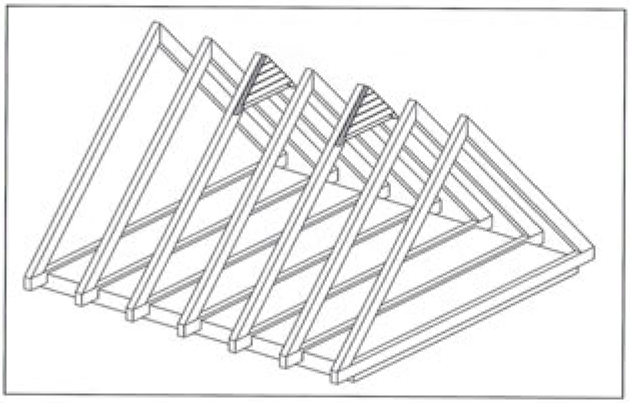

Figure 177: Crevice roosts in attics (rafter roof).

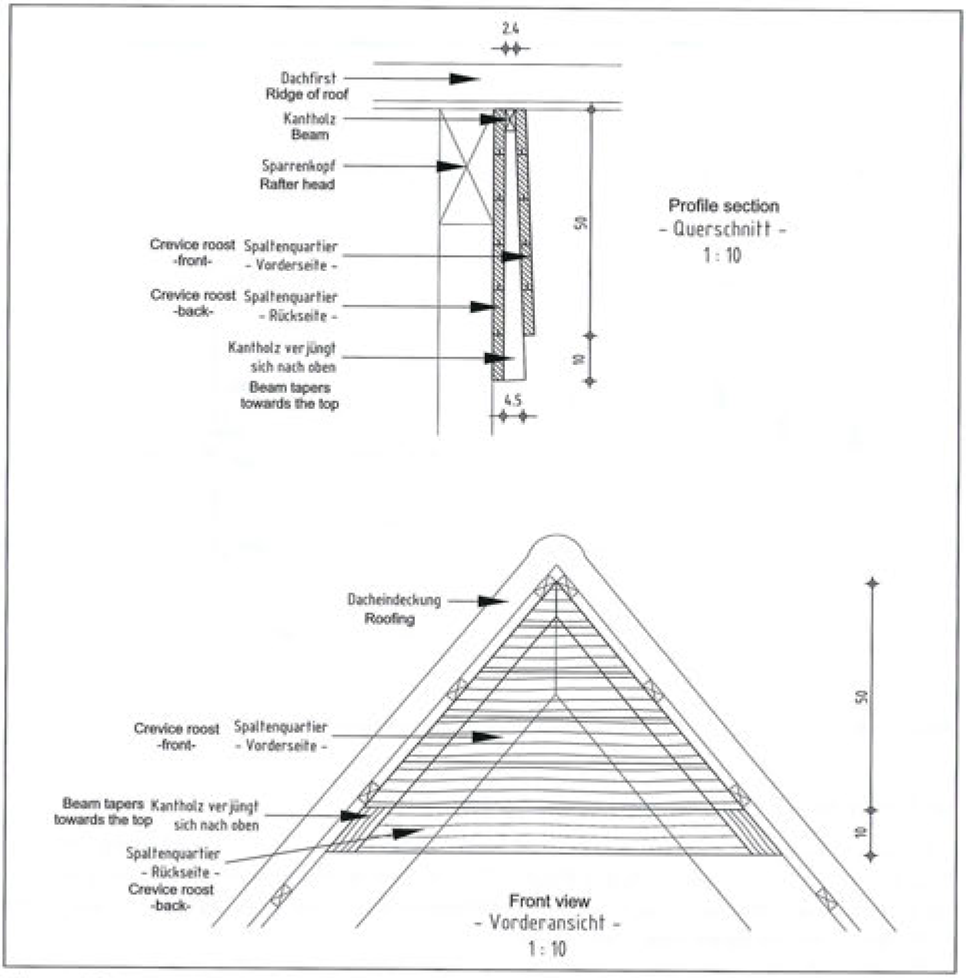

Figure 178: Sketch of crevice roost in attic (rafter roof), cross-section and front view.

10.2.3.7 Dormer window with bat fly-in entrance (category IV)

To create a fly-in opportunity for bats in attics, the movable casement of a dormer window can be taken off and can be replaced by a water-proof zinc sheet (put on a slant) (see figure 179). Additionally a rough landing board has to be installed for the bats (see figure 180). The bats are still able to fly into their roost freely without this landing aid, however, without it there would be no protection against pidgeons.

This entrance method can be used by those bat species which roost in attics, particularly the greater mouse-eared bat, long-eared bats and also Natterer's bat.

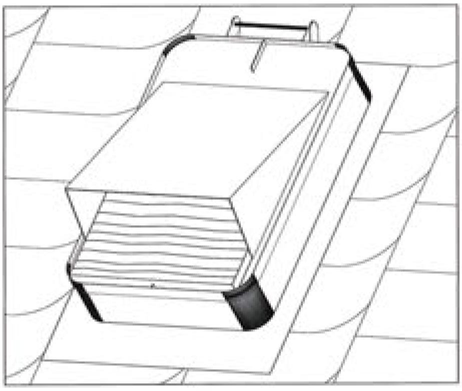

Figure 179:
Dormer window bat fly-in entrance and landing board (pidgeon-proof).

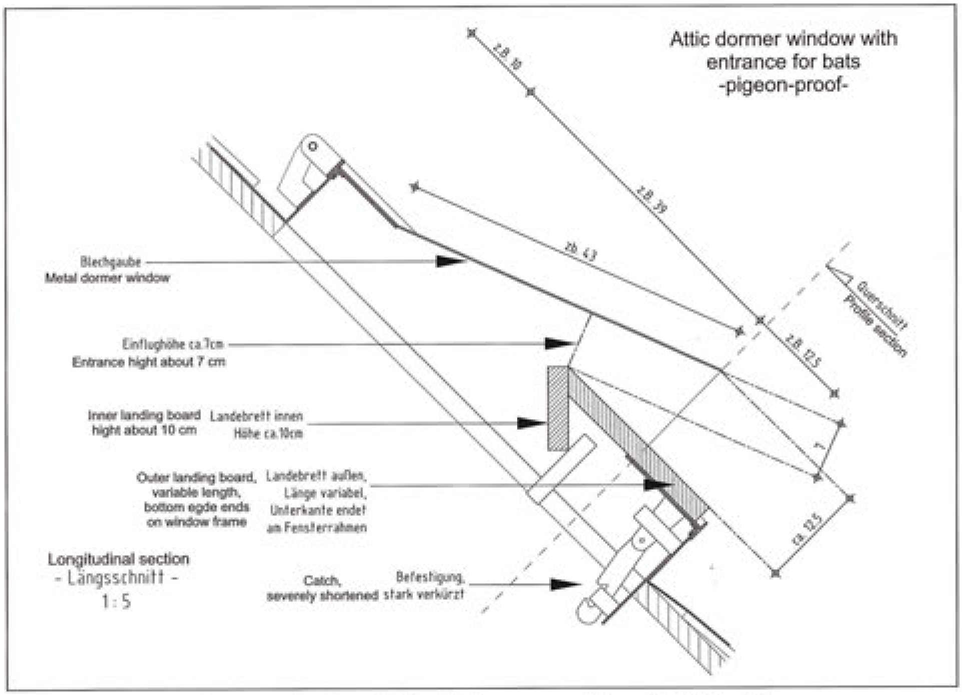

Figure 180: Sketch of dormer window with bat fly-in entrance in longitudinal section.

10.2.3.8 Ventilation dormer window out of zinc sheet (category IV)

The Ventilation dormer window is an opening of the attic, which guarantees an open fly-in entrance. Additionally a rough landing board is fixed below the dormer window for bats to crawl through (see figure 181).

This entrance method can be used by those bat species which roost in attics, particularly the greater mouse-eared bat, long-eared bats and also Natterer's bat.

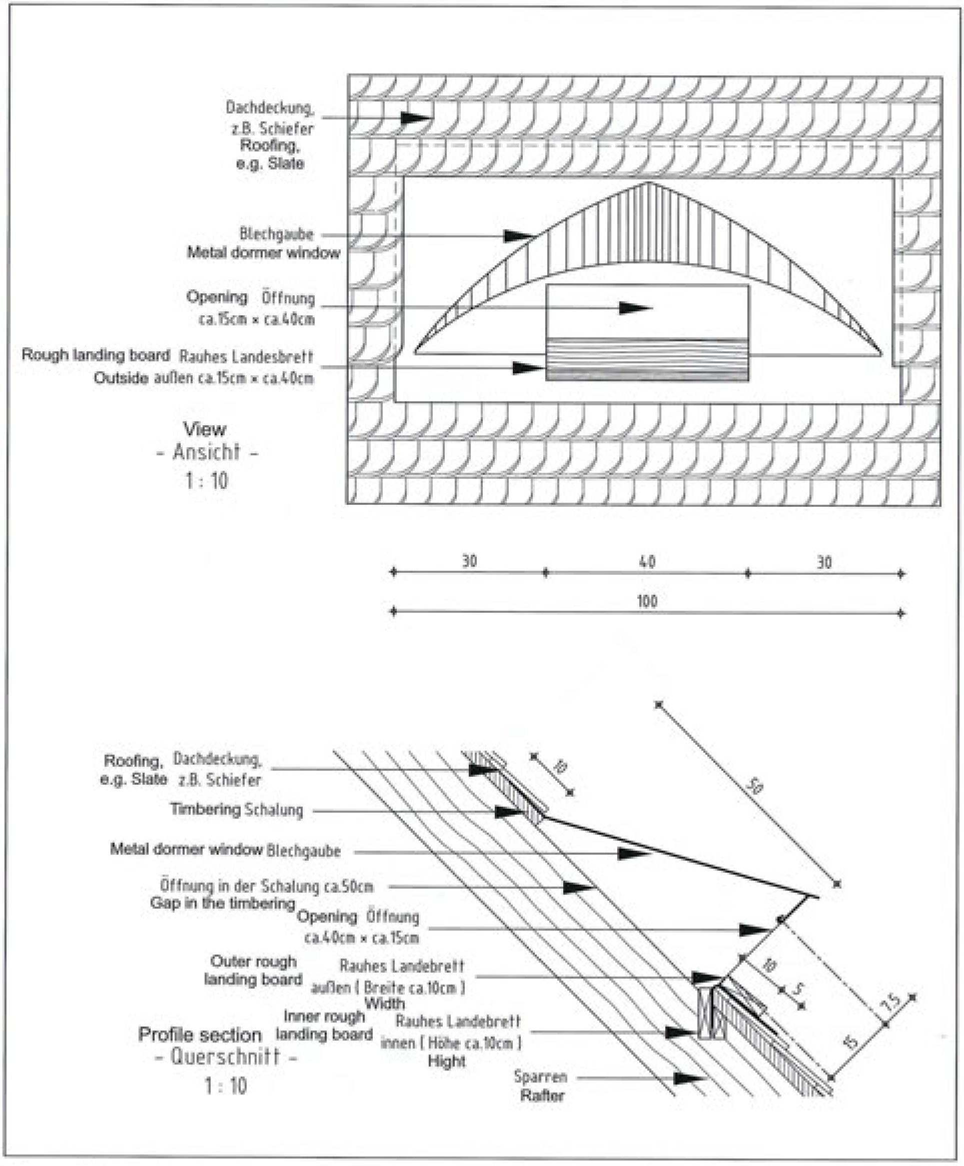

Figure 181: Ventilation dormer window out of zinc sheet, top view and cross-section.

10.2.3.9 Wooden shutter in gable window with fly-in crevice (category IV)

A wooden shutter in front of a gable window is shortened by 15 cm at the top (not pidgeon-proof, free bat flight into attic possible) or by 5 – 7 cm (pidgeon-proof, no free bat flight into attic possible) (see figure 182). The pidgeon-proof variant additionally has to be roughened on the surface beyond the crevice or has to be provided with 2 mm deep cross-grooves (landing area for bats crawling into their roost).

This entrance method can be used by those bat species which roost in attics, particularly the greater mouse-eared bat, long-eared bats and also Natterer's bat.

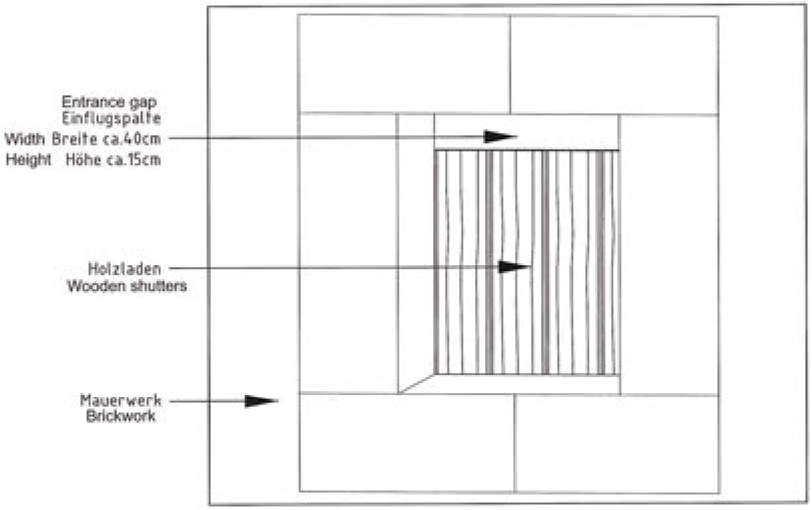

Figure 182: Wood shutter in gable window with entry hole (not pidgeon-proof). A 5 – 7 cm high fly-in entrance gap is pidgeon-proof, but does not allow bats free flight into the attic.

10.2.4 Spatial distribution

The number and density of bat roosts within the villages intensively investigated have proved to be surprisingly high during the course of the project (see chapter 7.2). For example, in one village 29 maternity roosts of the common pipistrelle were found within three years. In one summer a maximum 16 maternity roosts were occupied. With so many roosts known and varyingly occupied over several years, the problem is that new roosting opportunities may be quickly discovered and explored but then occupied much later.

Looking at the distribution of newly created potential roosts able to be checked (figure 183), it is noticable that measures to create roosts were usually applied to only one building in any one village. Only in one village new potential roosts were constructed in 9 or 10 buildings. Of the 72 villages where new potential roosts were created, 56 had their bat stocks investigated. No bat stock investigations were carried out in only three of the villages where more than one roost creating measure was carried out.

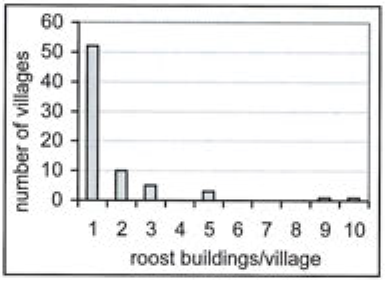

Figure 183:
Frequency of buildings (n = 121) in villages in the Marburg-Biedenkopf district (n = 72) where checkable newly created potential roosts were installed.

10.3 Control to determine success of newly created potential roosts

The checks to determine success of newly created potential roosts always took place in September at the end of the maternity period in the years 1998, 1999 und 2000. A final control, in which also roosts difficult to access were inspected, was carried out in February 2002. The controls were intentionally delayed until the end of the maternity period, as in this way the total happenings of the relevant summer months could be recorded. Roost switching and reconnaissance flights often take place at the end of summer. Due to the late date of the controls, bats could be found only rarely occupying the newly created potential roosts. The controls were mainly carried out to find indirect evidence of bat occupation or exploration such as droppings. The excrement of long-eared bats (*Plecotus* spec.), the greater mouse-eared bat and the serotine bat could clearly be assigned. The excrements of the smaller bat species (common pipistrelle and whiskered bat) could not be assigned with certainty.

Torches, binoculars, or mirrors were used during the routine controls and an endoscope in the exhaustive final inspection. Some newly created potential roosts were structured in such a way that boards could be taken off or unscrewed or had hinges and could be opened up.

Crack roosts in outside walls proved difficult to check reliably for occupation, as the small amounts of excrement that fall down can disappear quickly, e.g. washed away by rain.

10.3.1 Usage rate of newly created potential roosts

A distinction was made between newly created potential roosts in buildings ‚with previous use‘ (∑ 53) and ‚without known previous use‘ (∑ 68). Figure 184 shows the usage of newly

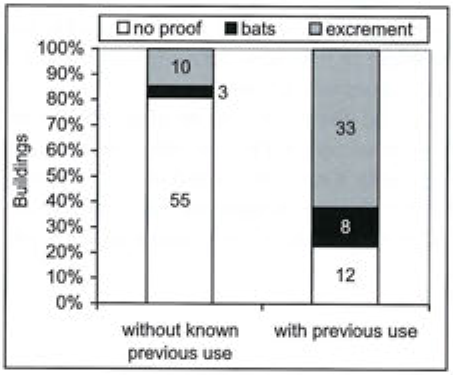

Figure 184:
Actual usage of the newly created potential roosts at 121 buildings realised in the project ‚with and without known previous use‘.

created potential roosts ‚with and without known previous use‘. The findings differ in regard to ‚no proof‘, ‚excrement‘ and ‚animals‘. Only just 20 % (13 of 68) of ‚new‘ roosting opportunities (without known previous use) were used by bats (see figure 184). Compared to that, bat excrement was found at 62 % of roosting opportunities ‚with previous use‘ (33 of 53) and at eight further roosts (15 %) animals were detected directly. Roosts ‚with previous use‘ are mainly church attics. Church attics are apparently visited regularly by bats because of few disturbances and the old building substance. Thus the fast exploration rate of new roosting opportunities in these buildings is not very surprising.

10.3.2 Which bat species use the newly created potential roosts?

The probability of finding bats during the inspections of newly created potential roosts was relatively low, because the inspections were intentially carried out after the maternity period. Bats were found occupying roosts in scattered cases, for example common pipistrelle (gable panelling inside with access from outside, bat roosting board and hollow concrete blocks), and common and grey long-eared bats (each in double-walled bat roosting board in ridge of attic) (see table 42). In one case a smaller species (probably com-

Table 42: Overview of roosts in which indications of bats were found in the years 1999, 2000 and 2002 (? = unknown, MR = maternity roost, IR = individual roost).

Roost offer	Date of completion	Bat proof		
		1999	2000	2002
Crevice roost (ridge) in attics	01.04.1999	*P. auritus*	*P. auritus*	*Plecotus*-excrement
Crevice roost (ridge) in attics	25.06.1998	*Plecotus spec.*	*Plecotus*- excrement	?
Crevice roost (ridge) in attics	10.11.1998	*Plecotus spec.*	nothing (excrement in the church)	*Plecotus*-excrement
Crevice roost (ridge) in attics	24.07.1998	old and fresh excrement	fresh *Plecotus*-excrement	nothing
Crevice roost (ridge) in attics	15.04.1999	much excrement	much fresh excrement (*M. nattereri*)	little excrement (*M. nattereri*)
Crevice roost (ridge) in attics	16.03.1999	*Plecotus*-excrement, Totfund	5 *P. austriacus*	*Plecotus*-excrement
Crevice roost (ridge) in attics	25.06.1998	much *Plecotus*-excrement (known roost)	new *M. myotis*-excrement, much *Plecotus*-excrement along ridge beam	*M. myotis*-excrement and *Plecotus*-excrement, but not under roost
Crevice roost (ridge) in attics	02.10.1998	*M. myotis* (IR, old)	*M. myotis* (IR, old)	*M. myotis*-excrement (not under roost)
Crevice roost (ridge) in attics	01.04.1999	nothing	2 *M. myotis* hanging places	?
Opening of attic (abandoned roost)	03.06.1997	*M. myotis*	*M. myotis* (mating roost!)	*M. myotis*-excrement

Table 42: Continuation

Roost offer	Date of completion	Bat proof		
		1999	2000	2002
Gable panneling inside with access from outside	30.09.1999	in November: excrement of a small species	*P. pipistrellus*	old excrement of a small species
Gable panneling inside with access from outside	24.06.1998	little excrement of small species	no new proof	old excrement of a small species
Gable panneling inside with access from outside	18.08.1999	?	nothing	*M. myotis*, *E. serotinus* (both several crumbs of excrement)
Crevice roost under roofing with access from outside	07.05.1998	*Plecotus*-excrement (not under roost)	nothing	*M. myotis* (several crumbs of excrement)
Crevice roost under roofing with access from brick with a hole	01.04.1999	nothing	nothing	several crumbs of excrement of a small/medium species
Crevice roost under roofing with access from outside	18.08.1999	?	nothing	several crumbs of excrement of a small species
Crevice roost under roofing with access from outside	?	?	?	several crumbs of excrement of a small species
Bat box in ridge	29.04.1997	nothing	*M. myotis*-excrement (1 crumb)	nothing
Bat board	24.07.1998	excrement of a small species	excrement of a small species (MR)	excrement of a small species (MR)
Bat board	01.04.1999	*P. pipistrellus*	no new proof	excrement
Bat board	10.07.1998	nothing	nothing	*P. pipistrellus* (single bat)
Cladding	25.06.1998	excrement of a small species	no new proof	excrement of a small species
Opening of shingle cladding	29.09.1998	?	nothing	few excrement of a small species
Hollow concrete block	?	*P. pipistrellus* (MR)	*P. pipistrellus* (MR)	

mon pipistrelle) used a bat roosting board as a maternity roost. Greater mouse-eared bats could be discovered in peg holes (new entry opening) in a formerly deserted attic. Otherwise the presence of bats was proved by excrement. The excrement was often just single "crumbs" in the roosts. This points more to an exploration of the roost than an occupation.

10.3.3 Temporal perspective of the process of reconnoitring or inhabiting roosts – How fast are potential roosts discovered or inhabited?

The availability of potential roosts during the maternity period is central to the interpretation of the process of roost exploration. To simplify the evaluation, the relevant period of roost exploration was divided into two periods: April to May and June to September. In this way a roost newly installed or optimized in December is tallied as first being available to bats in April of the following year. This solution avoids the difficulties inherent in evaluating measures taken (to make roosts available) over the whole year.

Figure 185 allows one to compare in steps of three months how long it took until an inspection afforded the first evidence of bats in a total 121 buildings where newly created potential roosts were installed. One can also see how old the potential roosts were that had no evidence of exploration or habitation by bats at last check. The oldest and thereby longest available potential roosts are 18 to 21 "months maternity period" old, that is to say, three summers old. The latter roosts numbered only four (two with evidence of use by bats and two without). This merely means that a few of the oldest potential roosts were "discovered" before they reached a high age and thereby disappear into a "younger" age group.

Not surprising is the high percentage of potential roosts accepted in buildings that had been "used before". The probability that bats will seek additional roosts in attics where they have been before is much greater than for attics never before used by bats. However, four "true" new acquisitions (with no prior known use by bats) were used already within the first six months (see figure 185). This confirms experience that common pipistrelles regularly move quickly into crevice roosts in non-plastered new constructions.

New roosts that replaced destroyed ones (roost replacement) remain without evidence of bat presence (up until now). It could be that the roosts were not used within the period of inspections or that roosts are not necessarily used every summer.

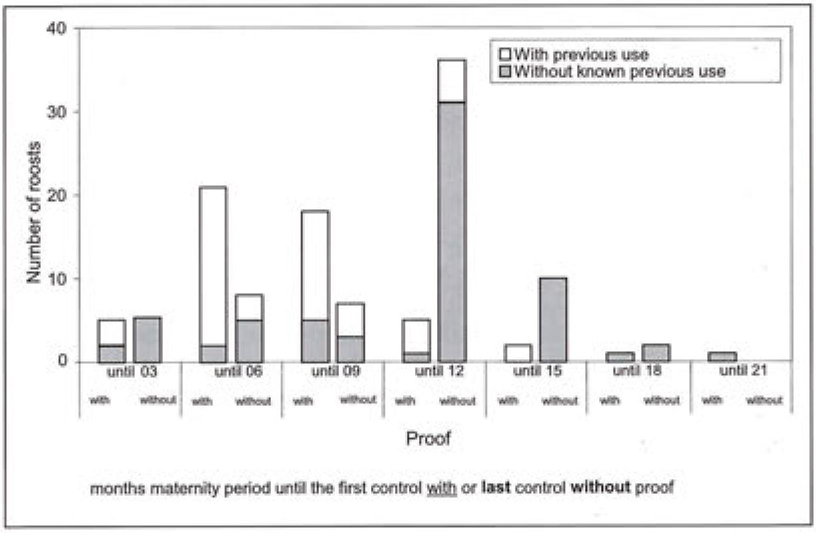

Figure 185: Use of newly created potential roosts in 121 buildings in the maternity period (April to September).

10.3.4 Which type of newly created potential roost finds most acceptance?

The above-mentioned evaluation of the time taken to reconnoitre or inhabit a roost took each of the 121 buildings as a single entity. In contrast, to evaluate which type of roost found the most acceptance, each single potential roost was counted (n = 193, see above). For example, three crevice roosts in the "ridge" area of an attic were counted as three potential roosts and not as one 'crevice roost, interior (ridge)'.

A final field check of all potential roosts (carried out in February 2002) also included those newly constructed or optimised roosts that were difficult to reach. These results were then compared with those from previous controls. This raised the number of potential roosts in the evaluation from 193 to 252. In figure 186 the total number of potential roots (individual newly created or optimised roosts) are divided into 8 groups, differentiated according to whether the roost was newly created or optimised. This differentiation is important here, just as it was in the first evaluation, because optimised roosts (optimisation) had a higher chance of acceptance than newly created roosts.

'Panelling gable wall, exterior' was evaluated separately from 'panelling, exterior' because gable walls frequently have an additional structure preferred by bats, namely hollow concrete blocks. Furthermore, 'bat roosting board interior' and 'bat box interior' were not evaluated as one entity, because each meets different requirements for roosts. The former are especially attractive to crevice dwellers, because they allow a belly-back contact, and this is not the case for the more spacious bat boxes.

The type of roost with highest acceptance is the 'interior panelled gable wall with outside access' (see figure 186). Seven (38.9 %) of the 18 newly created crevice roosts were used by bats. Providing an opening into the attic also appears to be successful. Evidence of bat usage was found in three of the seven potential roosts where an opening into the attic was newly created. Around a quarter of the newly attached bat boards were visited by bats. The roost designation 'crevice roost, interior (ridge)' is a typical attic roost and evidence of bats were found in 10 % of those newly created and 18 % of those optimised. These values are comparatively low. However, when viewing them it should be considered that several boards frequently were hung up in one attic and it would be unlikely that all be used simultaneously. The usually small number of bats using any roost simultaneously (no maternity roosts) meant that usually only one boards was used (see also table 45). A further factor in the evaluation of optimised roosts is the fact already mentioned that there is "competition" with naturally occurring crevice roosts.

10.3.4.1 Interior panelling with outside access

The results of controls on the 44 newly created potential roosts (in 23 buildings) designated 'interior panelling with outside access' are set out in table 43. Evidence of bat usage was found in seven (16 %) of the total 44 places where panelling was erected. Bat droppings in six roosts showed evidence of the presence of a smaller species, probably the common pipistrelle, and the other roost had droppings from three to four different species (greater mouse-eared bat, serotine bat, middle-sized species, small species). Only a small amount of bat droppings was found in any one roost, which points to the likelihood that the roosts were merely explored.

An evaluation of the type of entrance/exit opening showed that the 'entrance on eaves/gable' was most frequently used. The fact that the entrance/exit opening is situated beneath an overhanging edge matches the typical searching behaviour of bats, since bats orientate themselves using such features (see chapter 6.4). This type of entrance/exit opening "naturally" occurs most frequently.

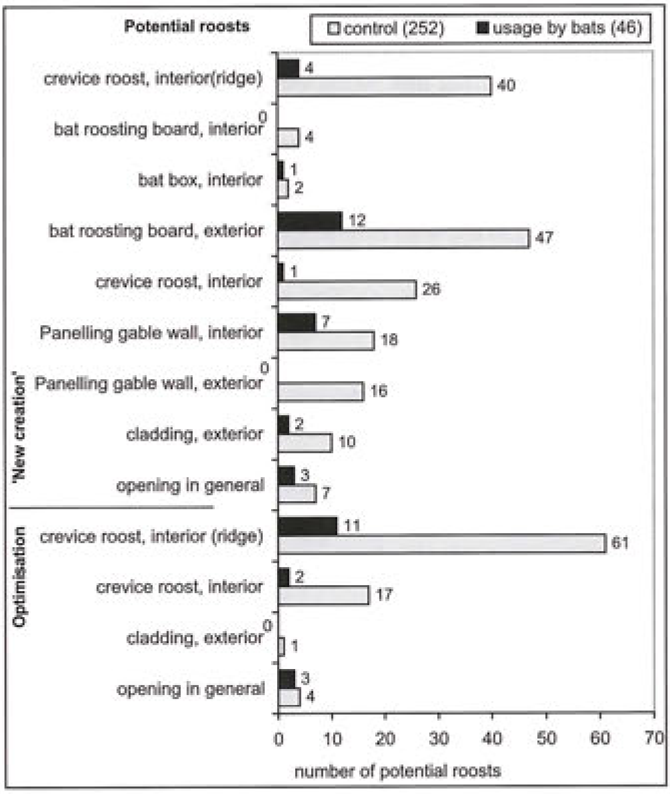

Figure 186: All newly created or optimised roosts (individual roosts, n = 252) grouped according to whether newly created or optimised, with details on which type of roost were used by bats (n = 46).

Table 43: Overview of roost type "interior panelling with outside access".

	Number of buildings	Therefrom used by bats	Number of roost in these buildings	Therefrom used by bats	Number of entrances to these roosts	Therefrom number of entrances to used roosts
Total	23	6	44	7	63	10
entrance on eaves/gable	**12**	**5**	**16**	**6**	**25**	**8**
With entrance at the surface of the wall	8	2	9	2	9	2
With entrance under windowsill	3	0	6	0	6	0
With entrance from the bottom (open/removed enclosure for insects)	4	0	20	0	23	0

10.3.4.2 Crevice roosts under roofing with outside access

Bats used four of the 15 crevice roosts under roof covering with outside access (checked in 11 buildings) (see table 44). The new roosts were entered via the roof eaves (two roosts) or a ventilation brick (two roosts). The bats involved (as evidenced by bat droppings) were a greater mouse-eared bat in one roost (entry via a ventilation brick), a small species, probably common pipistrelle in two roosts (entry via a ventilation brick and eaves) and a small and a large bat species in the other roost (entry via eaves). In all cases there were only small quantities of droppings, pointing to a low level of usage.

Table 44: Overview of the roost type crevice roost under roofing with outside access, and its usage in relation to type of entrance.

	Number of buildings	Therefrom used by bats	Number of roost in these builsdings	Therefrom used by bats
Total	11	4	15	4
With entrance on eaves	6	2	8	2
With entrance via ventilation brick	5	2	7	2

10.3.4.3 Crevice roosts in attics

A total 89 crevice roosts were checked for bat evidence in 58 attics. Of these, 22 roosts (in 16 attics) showed evidence of bat usage (see table 45). This shows that a quarter of potential crevice roosts in attics were used by bats. However, since many of the attics already had been inhabited or used by bats, this was often a case of making the bats' continued presence visible (see table 45). All the same, six (15 %) of the 40 attics that had been uninhabited up to this point or had been abandoned were visited by bats for the first time or revisited.

Table 45: Overview of usage of crevice roosts (CR) in attics with new openings, in relation to previous use.

	Number of attics with CR	Therefrom used by bats	Number of CR in these attics	Therefrom used by bats
Total	58	16	89	22
attic „uninhabited"	35	5	51	5
attic „abandoned"	5	1	9	1
attic „inhabited"	18	10	29	16

10.4 Final evaluation of newly created and optimised potential roosts

The creation of potential roosts needed some time to get going, so that the control of the roost offers was delayed. The final control took place in February 2002. Therefore, the possibility cannot be excluded that some excrement crumbs had already "disappeared" or decomposed, making the proof of bats impossible. The inspection of the newly created potential roosts was partly very difficult, as the roosts were only accessible with ladders and had to be unscrewed or viewed with an endoscope. Furthermore, the control had to be arranged with the householders, so that a detailed planning phase was necessary.

A short occupation of some of the new roosts during the first half of the year after their creation is worth noting. In contrast, no proof of the occupation of bats could be furnished at many new potential roosts after two summers. Most of the roosts had only little amount of bat excrement. This indicates that the newly created potential roosts are explored by the bats, but not necessarily used more intensively. It seems that bats more or less regularly "scan" a vast part of their surroundings to search for potential roosts. It is possible that many potential roosts are just explored, and only later used for spending the day (compare chapter 6.2). Therefore, it would make sense to only carry out the next roost inspection about 5 years after the last check.

The following main aspects can be evaluated as positive:

- Many roost offers are found by the bats and at least inspected.
- Very different types of roosts are accepted.
- Six house-dwelling species (common and grey long-eared bats, greater mouse-eared bat, common pipistrelle, serotine bat and Natterer's bat) used newly created potential roosts.
- A bat roosting board was used as maternity roost, probably by common pipistrelles.

In what way the roost offers are used regularly, e. g. as maternity roosts, cannot be said at the moment. This requires further roost inspections at a later date.

Still it must be said that the "creation of new roosts" on and in buildings depends on many "outside factors", which often limit a systematic procedure. Thus for example, it must be considered that:

1. Owners of buildings must be found who in principle want to have a potential roost;
2. The owners of the buildings must agree to the actual type of potential roost suggested being erected or installed;
3. The roost construction remains within an economically acceptable framework; and that
4. A skilled worker carries out the measure professionally and quickly.

Apart from the above, the bat occurrences in the environs of the newly created potential roosts should be known. This is important to consider for the evaluation, as a new occupation should take place faster in villages with a high density of bats. These aspects already indicate that a systematic and scientifically standardised procedure is really only possible in theory. Therefore it remains difficult or even impossible to judge exactly whether offers of new roosts can stabilise or increase bat stocks. Due to the insights concerning the regular destruction of roosts by renovations and other measures (compare chapter 9), it seems to make sense and to be essential to create several new potential roosts, for example in villages where a redevelopment of the old part of the town is planned. Apparently, bats are able to find new potential roosts relatively quickly.

10.5 Summary

Characterization of the roost offer

- The new creation of potential roosts had a certain phasing-in period, so that the inspection period was relatively short.
- The created roosts were distinguished according to 'with former use' (known bat activity at the roost locations) and 'without known former use' (real new creations of roosts)
- Different types of roosts were created. On the one hand, roosts can be directly integrated into the buildings during renovations or actual construction of the building (e. g. gap roost behind facades or behind beams) or can be erected later into or onto the building (e. g. bat roosting board or gable wall pannelling with access from outside).

- Single creation of new potential roosts within villages were the rule, but in two villages 9 and 10 potential roosts were built.

Effectiveness of the newly created and optimized potential roosts

Four out of 14 (28.6 %) "real" newly created roosts (where the building had no known former use by bats) were already used by the bats within the first six months. In comparison, bat excrement or bats occupying the roosts could be found in 77 % of the roost offers in buildings with former use by bats (33 out of 53).

- The roost type which is accepted most often, is the **gable wall with inside panelling, accessible from outside** (see figure 186). Seven (38.9 %) of these 18 newly created gap roosts were used by bats. There was evidence of bats on three out of seven newly **opened**, formerly used **attics**. About a quarter of the **bat roosting boards** erected were visited by bats. **Gap roost, inside (ridge)** is a typical roost in attics. A total 10 % of the real newly created potential roosts or 18 % of the optimizations were accepted as roosts.
- Due to the timing of the inspections, bats could be found directly in the roost only on exceptions: **common and grey long-eared bats** in gap roosts in the attics' ridges, **common pipistrelles** using bat roosting boards, hollow concrete blocks or the gable panelling, **greater mouse-eared bats** in peg holes of a deserted, opened attic.
- A **maternity roost** group of bats, probably **common pipistrelles**, could establish themselves in a bat roosting board (great amounts of excrement pellets of small size).

Final evaluation of the new creation and optimization of roosts

- Many of the newly created and optimized potential roosts are found by the bats within a short time.
- Up to now, the observation prevails that the roosts are mainly explored in the first three months, but not used for daytime occupation for the long-term.
- Very different types of roosts are accepted.
- Six house-dwelling species (common and grey long-eared bats, greater mouse-eared bat, common pipistrelle, serotine bat and Natterer's bat) were all found in the newly created or optimized roosts.
- In principle, the roost offers developed within the project's framework are adequate to present new shelter to bats.
- Numerous potential roosts should be offered especially where there are large redevelopment or restauration projects being carried out (e. g. town centre redevelopment or village restauration).

The mid to long term significance of the creation of new roosting opportunities can only be judged after further inspections of the newly created and optimized potential roosts.

11 Landscape features and distribution

11.1 Introduction

Has been known for some time that bats have a strong tie to landscape features (e. g. BLAB 1980). Especially at regulary used flight paths it was often observed that bats mainly conspicious structures for commuting and foraging (e. g. LIMPENS & KAPTEYN 1991, VERBOOM & HUITEMA 1997). EICHSTÄDT & BASSUS (1995) observed a transfer flight of a common pipistrelle oriented mostly on linear landscape elements. JANSEN (1993) records likewise the flight of common pipistrelles to their foraging sites along edges of forests, tree rows, riparian vegetation and avenues. According to LIMPENS & KAPTEYN (1991) common pipistrelles use linear landscape elements as foraging sites as well as marks for the routes of their flight paths.

In addition, there must be coherence between the landscape features and the pattern of occurrence of bat species. The research of SPEAKMAN et al. (1991) for instance, shows that most of Scotland's known maternity roosts are located near larger streams whose banks are lined with riparian vegetation.

The intensive surveys in the project area provided a good overview of the pattern of occurrence of the species and established a basis to verify the coherence between bat species and landscape features. It was furthermore expected to verify whether certain flight paths towards the foraging sites can be identified as going along linear landscape elements.

The following analysis was compiled using examples and is therefore differently elaborated, according to the various species and the depth of investigation in respect to methodology (detector based surveys to telemetry) and intensity of analysis (basic measurement to GIS-supported analysis).

11.2 Correlation between occurrence of particular bat species and specific landscape features

11.2.1 Common pipistrelle

The common pipistrelle was the bat species most commonly found during detector surveys in villages of the project area. Individual roosts or maternity roosts were detected in about 95 % of all villages. No roosts were found in only 5 (= 7 %) of the 70 mapped villages and, despite multiple surveys, exclusively individual roosts in 14 other villages (see chapter 4.1).

The relationship between the occurrence of the common pipistrelle (maternity colonies) and the landscape was to be clarified by a comparison of villages *with* maternity roosts ("roost villages") and *without* maternity roosts of the common pipistrelle ("zero villages"). This approach is based on the assumption that there should be fewer or no common pipistrelles in landscapes with insufficient landscape features, whereas the presence of maternity roosts should indicate the "better suited" landscapes. The comparison was therefore carried out between the 19 villages without maternity roosts of the common pipistrelle (see above) and 19 other villages with maternity roosts (random samples). Since common pipistrelles prefer to hunt in riparian vegetation or along inland waters (DE JONG & AHLÉN 1991, EICHSTÄDT & BASSUS 1995, JANSEN 1993, OAKEKEY & JONES 1998, RACEY & SWIFT 1985, RYDELL et al. 1994, SPEAKMANN et al. 1991, SPEAKMANN et al. 1995, STUTZ & HAFFNER 1985, TRAPPMANN 1996, VAUGHAN et al. 1997, WALSH & HARRIS 1996a, WALSH & HARRIS 1996b) and at edges of forests or within forests (DE JONG & AHLÉN 1991, EICHSTÄDT & BASSUS 1995, HARBUSCH 1996, JANSEN 1993), the two landscape parameters 'proximity to the nearest watercourse' and 'proximity to the nearest forest' were chosen for closer observation.

The distance to the nearest watercourse and to the nearest woodland was measured on a topographical map 1 : 25,000. Watercourses were grouped into four categories (see. table 46).

Table 46: Four categories of watercourses (TM 25 = topographical map 1 : 25,000).

Description	Presentation on TM 25
ditch / rivulet	1 line without name
small stream	1 line with name
stream	Double line
river	e.g. Lahn

The proximity to a larger watercourse seems to be important for the presence of maternity roosts. A total 10 out of 19 villages *with* maternity roosts of the common pipistrelle were located less than 600 m away from a larger watercourse (stream or river, see figure 187). The villages *without* maternity roosts of the common pipistrelle with the exception of four, were located near smaller watercourses. Two out of the four villages that were located near larger watercourses were more than 1 km away from these watercourses.

The parameter "proximity to the nearest forest" did not show such a strong result. Given that the roost villages were located near larger watercourses, the nearest forest was a maximum 450 m (an average 315 m) away from the village. The distance between the nearest forest to the zero villages without a larger watercourse averages from 130 to 1,360 m (an average of 460 m).

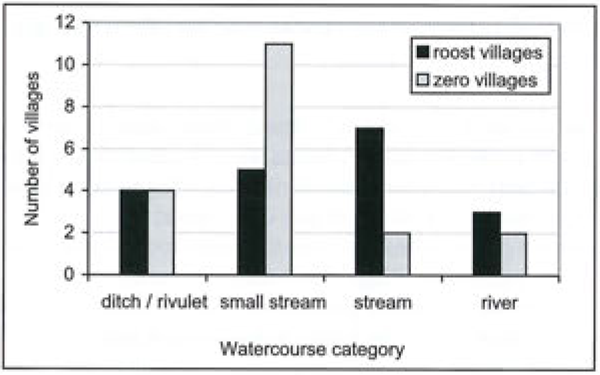

Figure 187:
Number of villages with and without maternity roost of the common pipistrelle (roost villages and zero villages) whose nearest watercourse is a ditch/rivulet, small stream, stream, or river.

11.2.2 Serotine bat

An evident concentration of serotine bat roosts is noticeable in the area of the Amöneburg Basin (Ohm River pastures) to the east of Marburg as well as along the Lahn River pastures (compare distribution map figure 19). Viewed at the level of microclimate, nearly all roosts are located in the warmer temperature area (see chapter 2.2). Also, compared to the remaining area of examination, the Amöneburg Basin is sparsely forested and predominantly used for agriculture (grassland outweighs). Telemetrical research showed that grassland belongs to the preferred foraging sites of the serotine bat. Four to five serotine bats, were seen hunting arthropods, probably beetles (dung beetles), simultaneously at low level flight over pastures. There is a clear correlation between the presence of serotine bat colonies and cow pastures. ROBINSON & STEBBINGS (1993) identified cow, horse, and sheep pastures, as well as the edge of forests to be the most frequent foraging sites of serotine bats. Serotine bats were observed to hunt at 3 m – 4 m heights, sometimes even as low as 30 cm (ROBINSON & STEBBINGS 1997).

11.2.3 Natterer's bat

At the beginning of the project, no Natterer's bat maternity roost was known in the Marbung-Biedenkopf district. The first maternity roost (in the ceiling of a cowshed) was discovered during the second year of research (1998).

Thereupon, within the scope of the detector mapping in villages, cattle sheds were specifically searched for appearances of Natterer's bats (78 villages). Evidence of this bat species could be found in about half of the mapped villages (37 villages). Maternity roosts could be found in 11 villages after intensive searching (including telemetry) (see chapter 4.4).

In order to analyse the relation between the occurrence of the Natterer's bat and certain landscape features, 20 villages with proof of the presence of the Natterer's bat (multiply surveyed villages) were compared with 20 villages without proof of their presence. A telemetry study within the scope of the project showed a homerange of maximum 2.8 km around the villages containing maternity roosts. Different landscape parameters (distance to the forest, forest area, percentage of deciduous, mixed and coniferous forest, edges of forests, open country, settlements, inland waters [flowing and contained], hedges and undergrowth) were investigated in a radius of 3 km around each village with and without proof.

The percentage of total forest areas near villages with proof of the presence of the Natterer's bat (42 %) is 13 % higher than near villages without proof (see figure 188). Within the a 3 km radius, the average of forested area around the villages with proof is 13.2 km² (±1.4 km² 95 % confidence interval), whereas the average of forested area around villages without

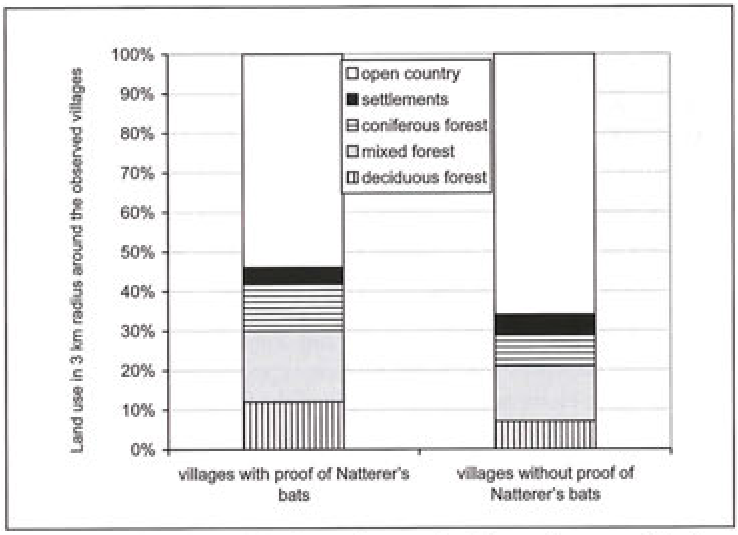

Figure 188: Percentage of land use and. landscape features in a 3 km radius around the observed villages with and without proof of Natterer's bats.

proof is 8.1 km² (± 4 km² 95 % confidence interval). There is also a clear difference in the distance to forest and to bodies of flowing water (see figure 189). The average distance from the village centre with proof of Natterer's bats to forest and to bodies of flowing water is 190 m (forest) and 70 m (body of flowing water). In villages without proof, the average distance is 630 m (forest) and 210 m (body of flowing water). In regard to the other reviewed parameters, no distinct differences were found, albeit to the fact that the percentage of open land in the area without Natterer's bats apparently dominates.

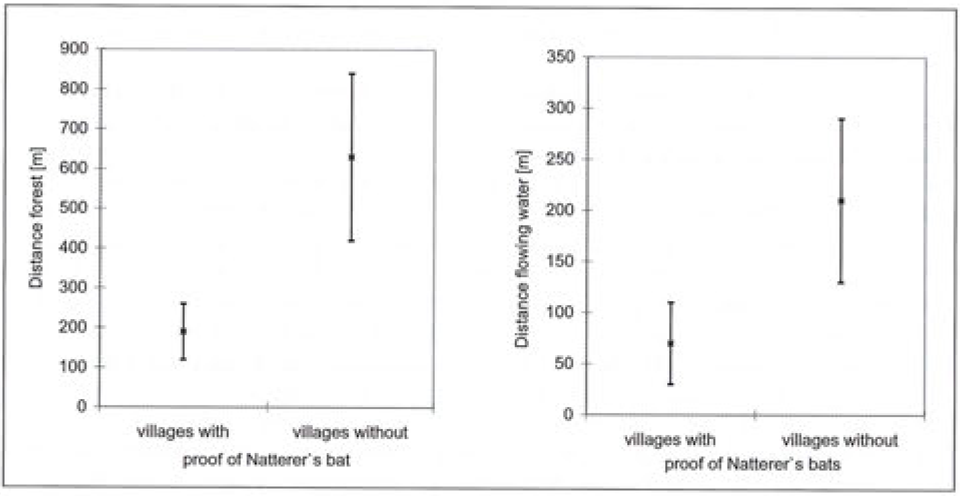

Figure 189: Average distance from forest (left) and from body of flowing water (right) to villages with and without proof of Natterer's bats.

It was also reviewed whether there is a correlation between the occurrence of Natterer's bats in a village and the level of cattle husbandry there (number of cattle and number of cattle farms in 1991 and 1999). However, no correlation could be found. It seems that a high percentage of forest areas and proximity to bodies of flowing water are of most importance to the distribution of the Natterer's bat (see figure 190).

11.2.4 Barbastelle bat

The foraging sites of barbastelle bats were analysed on two levels with the help of a GIS (Geographic Information System) (foraging site analysis). On the highest level, superior land use parameters and features of foraging sites were recorded (deciduous, mixed, or coniferous forest, clearings, open country, park landscapes and areas of human settlement). The inner edges of the forest, the boundaries between different types of forest or clearings, were classified and mapped as linear elements. The inner edge of the forest is a measure for the structural variety of an area. In order to analyse the structure of foraging sites even further, random 1 ha forest areas within all foraging sites were mapped more intensely (totalling 46 forest areas, each with 1 ha per 10 ha). Twenty-one structural parameters were recorded for each of these random hectares, such as exposition, type of forest, height of treetops, proportion of cover by the herb layer, shrub layer or tree layer, depth of mulch layer, amount of deadwood, length of forestry trails and waterlines, and distances to the nearest village and to the nearest road.

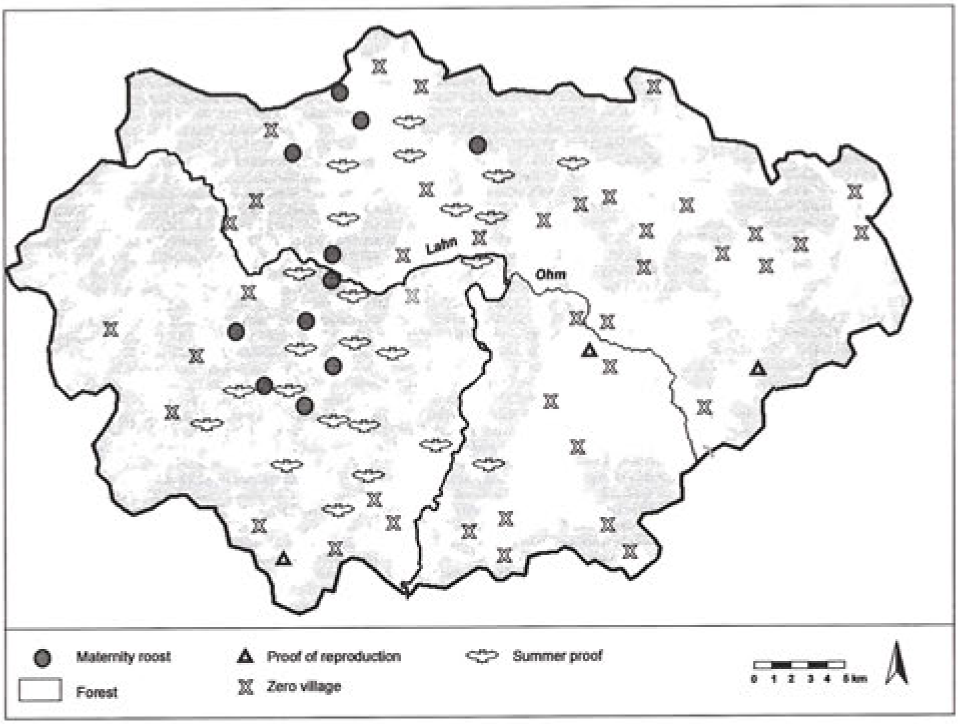

Figure 190: Villages with proof of Natterer's bats and the distribution of forest areas in the project area.

For both levels of analysis, random areas in a radius of 8 km around the maternity roosts were used for comparison. A computer was used to select 24 areas of 15 ha each (average foraging site size of the animals) for the first level of analysis. The overall size of areas used for comparison and the detected foraging sites were thus identical. As to the second level of analysis, 48 1 ha sized forest areas were chosen at random.

Apart from the analysis of foraging sites, the entire area was analyzed in a radius of 5 km around the maternity roost on the basis of 24 15 ha sized areas, with partly the same parameters as mentioned above (habitat analysis). Furthermore, the length of country roads, highways, federal roads and the expanse of undisturbed areas were admitted into the analysis as parameters. This analysis of habitat was also applied to further eight maternity roosts of the barbastelle bat in Thuringia und Bavaria, in order to enhance the sampling. Here as well, some areas for comparison were selected so as to show the particularities or differences from the "normal landscape". A total 15 areas of comparison were chosen at random within the three federal states Hesse, Thuringia, and Bavaria.

The foraging site analysis (level 1) showed that the foraging sites have a much greater proportion of forest (average of 82.5 %) than the randomly selected areas (average of 42 %) (see figure 191). Also, much more structural variety was present in the foraging sites (average of 8.5 inner edges of the forest per km) than in areas for comparison (average of 4.6 inner edges of the forest per km) (see figure 191).

The evaluation at the second level showed that the number of forest types (average 2.2), the circumference of beech trees (average 92.2 cm), and the classification of proportion of

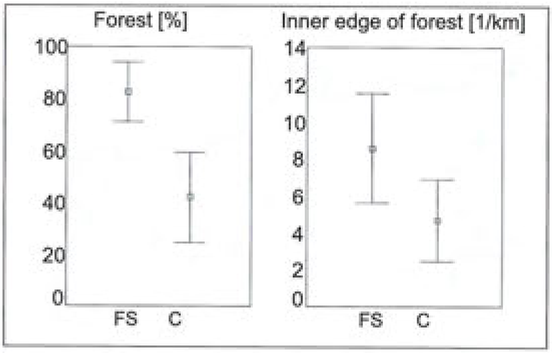

Figure 191:
Average percentage of forest (left) and average quantity of inner edges of the forest per km (right) within the foraging sites (FS) of the barbastelle bat and within the areas for comparison (C) with indication of the 95 % confidence interval (level 1).

cover by the shrub layer (average of 1.8) were higher in the foraging sites than in the areas for comparison (see figure 192). No characteristic differences were detected for parameters like quota of deciduous forest, covering of tree or herb layer, and tree height.

The habitat analysis showed that the areas around maternity roosts hold a much higher proportion of spaces undivided by roads than the areas for comparison (without considering country roads). Overall, the quota of settlements around the colony location is less than in the areas for comparison.

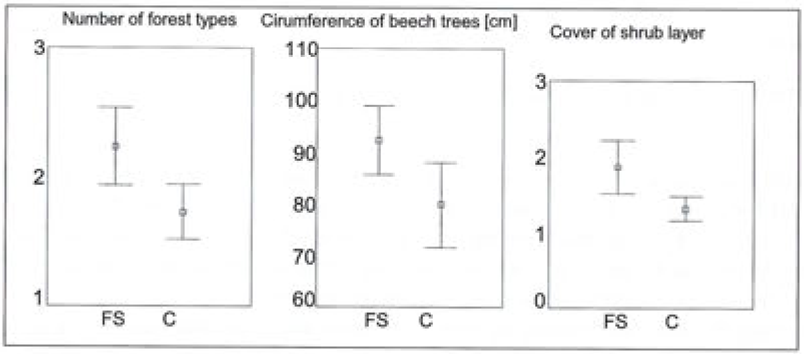

Figure 192: Average number of forest types (left), average circumference of beech trees (middle) and classification of proportion of cover by the shrub layer (right) within the foraging sites (FS) of the barbastelle bat and within the areas for comparison (C) with indication of the 95 % confidence interval (level 2).

11.3 Flight routes of different bat species

Observations of bat flight routes were not within the scope of the project and were therefore only recorded every now and then. However, because the flight route phenomenon has interesting aspects and because current knowledge has many gaps, some of the recorded flight paths will be described below.

Several methods were applied in order to track the bat´s flights from roost to foraging sites. Chemiluminescent light sticks were glued to the fur of common pipistrelles and serotine bats (compare chapter 3.1.7). One whiskered bat and two Natterer´s bats were tracked by telemetry.

Several **female common pipistrelles**, equipped with chemiluminescent light sticks, flew at first along a small developed road (lined in parts with trees and hedges) to the outskirts of their roost village and then turned to follow along an embankment (with copse) to reach a small river (Ohm), not the shortest possible route. Only the last stretch, approximately 100 m, was over a featureless field, i.e. without copse or other noticeable guiding lines (see figure 193). Individuals were observed hunting beside the river, along copses und over the river's surface (at approximately 2–5 m height).

The flight of common pipistrelles from the maternity roost to the foraging site could be observed at dawn – without further aids – at another village (Cölbe). Most of the animals (approx. 30 of 45) flew on a direct route of 375 m across open land (field) to their foraging site at the Lahn (see figure 194).

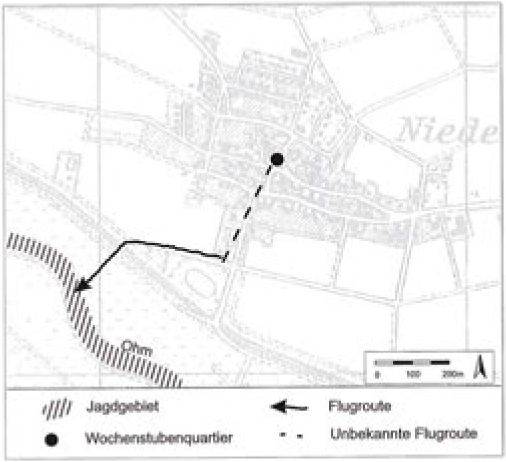

Figure 193: Flight path of female common pipistrelles equipped with chemiluminescent light sticks from their maternity roost to their foraging site at the Ohm River.

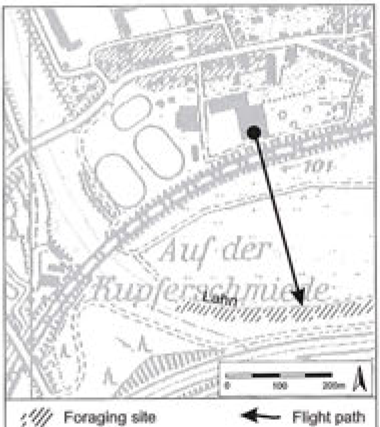

Figure 194: Flight path of common pipistrelles from their maternity roost to their foraging site at the Lahn River.

On their way to their foraging site (edge of a forest and bordering grassland), **serotine bats** equipped with chemiluminescent light sticks did not choose the shortest way over the forest but flew along the edge of the forest (see figure 195).

The radio-tracked **whiskered bat** also did not choose the shortest way across open country, but instead flew along the edge of the forest to her foraging site in the forest on several consecutive evenings (see figure 196).

At the end of June, a lactating **female Natterer's bat** flew back and forth repeatedly per night along hedges between its maternity roost and foraging site in a forest (see figure 197). Another female frequently used a stream lined with riparian vegetation as flight route between two foraging sites (see figure 198). At no time could it be sighted over open country.

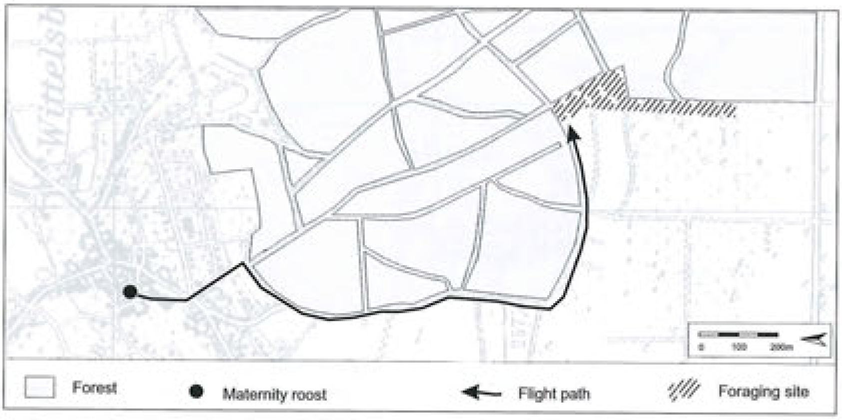

Figure 195: Flight path of serotine bats equipped with chemiluminescent light sticks flying from their maternity roost to their foraging site at a forest edge.

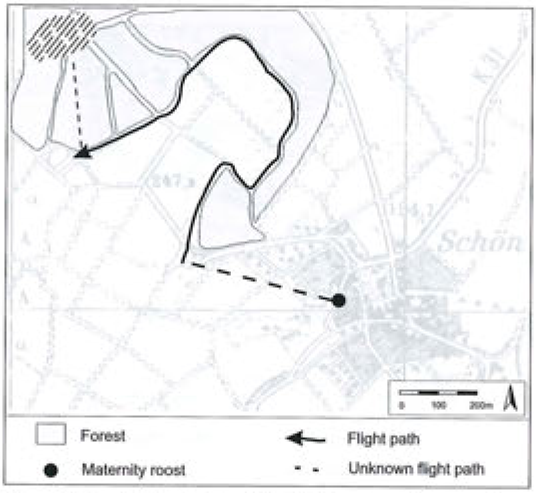

Figure 196: Flight path of a radio-tracked whiskered bat flying from its maternity roost to its foraging site in the forest. It used the same route on several consecutive days.

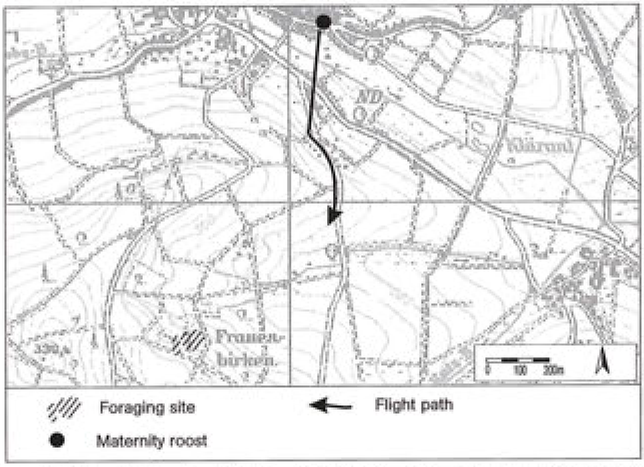

Figure 197: Flight path of a radio-tracked Natterer's bat flying from its maternity roost to its foraging site in the forest.

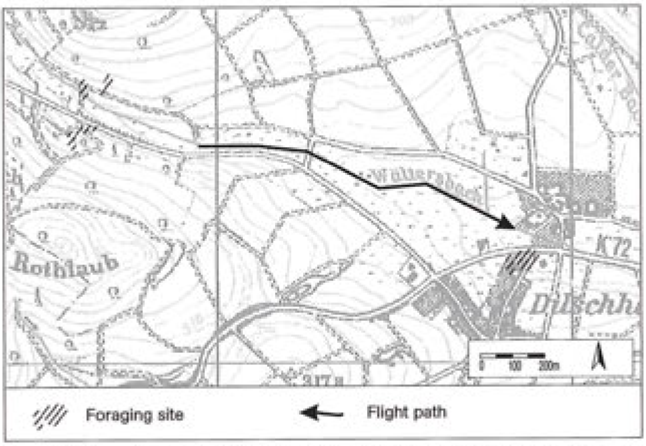

Figure 198: Flight path of a radio-tracked Natterer's bat flying between two foraging sites.

11.4 Summary

- The distribution of maternity roosts of **common pipistrelles** in structurally rich areas like Central Hesse is evidently linked to specific structures or landscape elements. Bodies of water play an important role. Localities with maternity roosts were located less than 600 m away from a larger body of water or maximal 450 m away from the nearest forest.
- **Natterer's bats** also prefer areas with specific landscape structures. The total area of forest (42 %) near settlements with evidence of Natterer's bats was higher than near settlements without evidence of Natterer's bats (29 %). Similarly there is a distinct difference in the distance to the forest (190 m in comparison to 630 m) and the distance to the body of flowing water (70 m in comparison to 210 m).
- Nearly all maternity roosts of **serotine bats** in the project area were located in sparsely wooded areas, in grassland (pastures) with warmer temperature conditions.

- The foraging site of the **Barbastelle bat** showed a much higher proportion of forest (average of 82.5 %) and a much higher structural variety than the area for comparison. In addition, the amount of forest types (average of 2.2), the circumference of beech trees (average of 92.2 cm), and the classification of proportion of cover by the shrub layer (average of 1.8) were higher at the foraging sites than in areas for comparison. The analysis of habitat in various federal states showed that the areas around maternity roosts feature a much higher quota of areas undivided by roads than the areas for comparison. Road traffic apparently plays a role in this species' choice of habitat.
- In two different villages, **common pipistrelles** chose the shortest route over open country to their foraging sites. In contrast, **whiskered bats** orientated themselves strongly on landscape structures and thereby accepted a longer route. **Serotine bats** could also be observed choosing flight routes along structures to their foraging sites. They were observed most often high above the guiding lines of these structures. Radio-tracked **Natterer's bats** used hedges or copses as flight routes on their way from the maternity roost to their foraging sites and between two foraging sites and are therefore clearly bound to landscape structures.

12 Synopsis

12.1 Project goals and hypotheses

The goals of the scientific investigation accompanying the T&D project that were mentioned in the introduction of this report could be achieved. Already in the first year of the project it was confirmed that there does exist a roost assemblage of maternity roosts in common pipistrelles and serotine bats. In the further course of the investigations, colony assemblages and other levels of the spatiofunctional relationships in bat populations were added – thus resulting in many consequences for nature conservation (compare chapter 7.6).

The premiss that bat conservation and modern construction and living is in principle compatible is not wrong, but the conservation of house-dwelling bats calls for special measures to be taken and inherently contains conflicts of interests. Next to the conservation of existing roosts, nowadays it is essential to create new roosts in order to balance the steady loss and destruction of roosts. Specific problems occur for those species of bat that depend on large attics, because most of these areas have been converted into human living space and large colonies are felt to be a nuisance (noise, odour and dirt). Nowadays, maternity roosts of the greater mouse-eared bat can virtually only be found in churches, castles and village schools (DIETZ & WEBER 2002).

Whether the size of the colony is directly related to the potential size of the roost assemblage could not be clearly verified. Proven are frequent roost switching in all house-dwelling species, i.e. maternity roost colonies must have several roosts in an assemblage at its disposal. The number of females in a maternity roost is influenced by the amount of available food in the area, as well as possibly by spatiofunctional relationships. Therefore a correlation between colony size and the offer of potential roosts cannot be analyzed solely by sheer monitoring of current bat stocks, but rather via complex experimental investigations.

12.2 Evaluation of danger to bats

The diverse ways of life of house-dwelling bats in different regions of Germany involve a diversity of dangers which can be disadvantageous for bats in individual places under certain circumstances. Nonetheless, below we undertake to classify the dangers and give them a weighting – starting with the factor marking the greatest threat for house-dwelling bat species – on the strength of our experience and knowledge gained in the Marburg-Biedenkopf district.

Destruction of summer roosts

According to our results, the loss of summer roosts, particularly within maternity roost assemblages, is the greatest threat to house-dwelling bat species (see figure 199 for an example of a roost closure). Despite the roosts being protected by law as the breeding, living and refuge places of protected animal species and appropriate technologies to conserve and create roosts being trialled, the number of roosts for house-dwelling bat species is nevertheless steadily shrinking. This is evidenced by the annual destruction rate of common pipistrelle roosts of up to 8 % and by the threat to every fourth serotine bat roost during the time of the project (compare chapter 9). The bats cannot meet their natural roost switching requirement without a sufficient number of summer roosts. A maternity roost which is too small may be unfavourable for the raising of young, i.e. the reproduction rate could drop or the death rate of young could rise if the mothers cannot evade a temperature anomaly or a parasite calamity in the roost. Also, the destruction of roosts in buildings are often connected with the killing of bats, namely if bats are ignorantly trapped, intentionally killed, or if juvenile bats get separated from their mothers (for roost closure see figure 199).

For bat species which are extremely loyal to the location of their roosts (e. g. the lesser horseshoe bat, BIEDERMANN 1997), the destruction of one maternity roost can directly lead to the demise of the affected colony. In contrast to roost switching species, these species cannot simply move to another roost.

Figure 199:
A maternity roost of common pipistrelles, blocked by styrofoam on an unrendered house wall of hollow concrete blocks.

Reduction or change in food supply and foraging areas

An adequate food supply is of course of primary importance for the survival of any animal. Native bats, though, have the ability to lower their body temperature and slow their metabolism and by doing so to outlast a time of food scarceness, e. g. should insects be scarce due to a cold spell. This is not only the case during hibernation in winter but over the whole year, whenever it is advantageous. This changes, though, for females in the maternity period. The pregnant and nursing females have to keep their body temperature steady, so that their offspring develop rapidly and may be nursed. A delay in growth of several weeks occurs over some chilly and wet summers and may be unproblematic. If the offspring take too long to become self-sufficient, however, they will probably not become acquainted with sufficient hibernacula (compare chapter 6) and therefore have a low survival probability. Consequently, mothers in maternity roosts are limited in using their ability to lower their body temperature or slow their metabolism. They are dependent on enough suitable foraging sites they can reach from their maternity roosts (compare chapters 6.3 and 7.5) and on a sufficient food supply. There is much danger for bats if interference with nature and landscape destroy or qualitatively damage their foraging sites and by thus doing, reduce the populations of arthropods, their important food source.

Fragmentation and isolation of habitats

The splitting of habitats into smaller areas (habitat fragmentation) causes increasing problems for bats and many other animals in landscapes influenced by human cultivation. The animals must be able to reach several foraging sites within one night, whereby structures along their flight routes play a major role (compare chapter 11.3). Besides this, contact to animals of the same species in neighbouring areas is important for genetic exchange within the regional population. The requirements for a frequent exchange seem to be fulfilled for common pipistrelles and serotine bats, as their populations are genetically strongly mixed, even though their females are philopatric. Because female serotine bats seldom change into another colony, their local population is in principle at risk due to isolation mechanisms (chapter 8). If no more suitable habitat is located in the wider surroundings of a colony (habitat isolation) and therefore no more bats of the same species can be found there, the affected colony is in danger of dying out. Therefore all alterations to landscapes that lead to a break in the connected biotope system, a fragmentation of habitat or the isolation of colonies are a peril for bat populations.

Research in the project showed that the areas around maternity roosts of barbastelle bats are fragmented much less by roads than the areas for comparison (compare chapter 11.2.4). Thus it must be concluded that roads can have an isolating effect on bats.

Disturbance and destruction of hibernacula

The mass hibernacula of common pipistrelles have a central function for the population in a catchment area with a radius of about 40 km. Over 20,000 animals come to Marburg Castle for swarming (chapter 6.2). There are also hibernacula of other species of special regional and even national importance (compare BFN 2003) and must therefore be protected at all costs. Because most of the known larger hibernacula already have security measures in place and all bat hibernacula are protected by law anyway, we do not judge damage to hibernacula to be of major problem in bat conservation. Of course, additional protection measures should be taken where hibernating bats are disturbed or hibernacula are in danger of being destroyed, particularly if the endangered roosts are of national importance (compare list in BFN 2003). But the extensive peril of house-dwelling bats due to a shortage of hibernacula is a thing of the past, thanks to decades of work in bat protection.

Direct casualties and timber preservatives

Casualties of individual bats can as a rule be absorbed by the bat population. Falling prey to cats, cars or ignorant people who only have something to do with bats by accident is therefore not a problem for nature conservation. Only if several individuals of a maternity roost die can predation by cats, traffic accidents, or direct human pursuit (outside the roosts) become a menace. Because this is rarely the case, we do not attach great importance to this danger for bats. The same applies to the use of timber preservatives, which are not considered to be a threat nowadays as long as they are not used on purpose to disturb or destroy a roost.

Open questions

The above evaluation of the factors endangering bats cannot be final, because many questions remain regarding biology and population ecology of house-dwelling bat species. We already mentioned some of these in previous chapters. When it comes to requirements for conservation, more problems need to be solved, e. g. how high the natural mortality of bats is and which death rate factors are affected by human activity, to what extent light and noise disturb bats and how large a maternity roost must be in order to persists in a long-term. Therefore, more research is needed for the conservation of bats.

12.3 Conservation of bats in areas where they have settled

The spatiofunctional relationships of house-dwelling bats to their environment (compare chapter 7) and the weighting of endangering factors determine the tasks and priorities of bat conservation. Essential measures are (sorted by priority):

1. Conservation of known maternity roosts (within the roost assemblage) and of the larger hibernacula.
2. Public awareness campaigns with the following goals:
   - Attraction of sympathy for bats and the protection of existing sources.
   - Information on the roost requirements of various species and the possibilities of creating new roosts.
   - Information about biology of bats, including the reasons for invasions, and the need to protect bats.

Public awareness work includes advertising, media work, events for and architects those who can disseminate information, as well as establishing a network of local bat conservation consultants.

3. Improvement of the fundamental data for local bat conservation, i.e.:
   - recording of bat species in the areas where bats occur,
   - targeted searches for summer roosts, particularly for maternity roosts,
   - mapping of frequently used foraging sites and flight paths,
   - identification of spatiofunctional relationships in a regional context.
4. Protection of foraging sites which are frequently used by maternity colonies.
5. Protection of the structures that connect habitat systems and preservation of other landscape elements which are of special interests to bats.
6. Safeguarding small hibernacula if specific perils exist (e. g. frequent disturbances near areas of human settlement), unless these are already wired off or made inaccessible to humans by other means.

Roost protection

The analysis of the characteristics of numerous bat roosts showed that the different species have a great variety and at the same time differing roost requirements. Notably preferred are roosts in intermediate roofs with exposure to the south and west. Also important are suitable landing places at the entrance gap. The best supply of roosts is in the old centres of villages.

The most potential roost spots are found there because of the age of the buildings (compare chapter 5).

Supplying potential roosts in villages is possible in principle, and is useful under well-defined premises (compare chapter 5 and 10). At first though, new roosts are gradually explored and are seldom used instantly as daytime refuges. At least six species profit from newly created potential roosts. Most successful are inside panelled gables with outside access and attics with appropriate access for bats (compare chapter 10.3). To install a purpose-built roost in an already completed building can be expensive in time and money. Also, it must be considered that bats use many roosts during summer season and that an individual additional roost would not have an enormous impact. It is therefore preferable to simultaneously install newly created potential roosts or optimize existing ones in as many buildings of a village, district or region (or even nation) as possible, and thereby take into account or use the predominant architecture or current redevelopment programmes. It is therefore essential to promote measures to create new potential roosts or optimize existing ones in as wide an area as possible in order to inspire as many homeowners as possible. At the same time, the building industry (architects, tradesmen etc.) must be made aware of the requirements of bat conservation, as was achieved in the T&D project through dissemination of targeted information, instructions for handling bats and construction examples (DIETZ & WEBER 2000, DIETZ & WEBER 2002). Points for the construction of potential roosts in areas of human settlement can be summarised as follows:

- First of all, a check of the "demand" should be carried out, i.e. one or more bat species should be chosen as the focus. A record of local bat stocks is essential.
- The location of potential roosts should be as near as possible to existing or former roosts.
- The creation of new potential roosts can concentrate on a single village, for example with existing maternity roosts in order to protect or care for the colony, or it can be carried out on a regional level in order to promote a network of currently more or less isolated occurrences of bats.
- An efficient and goal-oriented public awareness campaign should accompany such a project.
- It is recommended to evaluate the success of measures to create and optimise roosts.

12.4 Improvement of database for bat conservation

Targeted surveys that record all bat species equally well lead to a modified view of the occurrence of each species and their conservation status (chapter 4.9). Conservation measures for bats that lead to actual improvements of animal conservation presuppose a good data pool. The latter is to be achieved solely by local and regional recording of stocks. Common pipistrelles are common and easy to map. The greater mouse-eared bat, serotine bat and Natterer's bat can be mapped equally well, but there are still methodological problems with mapping other house-dwelling species (chapter 3.1.1). Therefore, combined efforts should be made to optimise the recording methods and to test them in many areas of investigation. A main coordination centre per federal state is needed for this – also to analyse monitoring data (BIEDERMANN et al. 2003).

The goal of a local or regional analysis of existing bat species and their (summer) roost requirements should be to locate as many of their dwelling places as possible. Systematic detector mappings play an important role here (compare chapter 3). These mappings should not only take place during the emergence period in the evening, but also in the early morning hours, when the animals swarm outside their roosts before entering. This applies especially, for example, to common pipistrelles, whiskered bats, barbastelle bats and long-eared bats. The serotine bat is a "special case", because it often swarms and enters its roost during the night. But there is still a possible extension to evening surveys with this species. At the time of becoming volant, when the young can be heard in their roosts (without detectors), the roost of serotine bats should be searched for in the middle of the night. The approach for mapping the Natterer's bat is different again: their apparent bond to cowsheds calls for a specific search in cowsheds during the night.

The targeted mappings, carried out appropriately for each house-dwelling bat species (see table 47), show that some species are clearly more common in central Hesse than previously assumed. This especially applies to serotine bats and Natterer's bats. A broadly spread public awareness campaign may already lead to new reports of some species, though only intensive detector mappings (preferably combined with trapping and telemetry) give a complete overview of distribution. The results of recording the occurrence of the Natterer's bat were more conspicuous. Not until targeted additional searches in cowsheds were undertaken did it become evident that this species is the second most common after the common pipistrelle in villages in rural regions. Even the presence of the barbastelle bat, which was believed to be nearly extinct in Hesse, could be ascertained by the discovery of one of the largest maternity roosts in Germany.

Table 47: The best times for mapping house-dwelling bat species (x = mapping recommended, xx = mapping most effective).

Bat species	Time of detector mapping		
	evening	morning	night
Common pipistrelle	x	xx	
Serotine bat	xx	x	x
Greater mouse-eared bat	x	xx	x
Natterer's bat		xx	xx
Whiskered bat	x	xx	
Common long-eared bat		xx	
Grey long-eared bat		xx	
Barbastelle bat	x	xx	

12.5 Demands on federal, state and local government

The federal government should further advance its existing efforts and successes in bat conservation. After many projects which were supported by federal funds within the last years (BOYE 2002), a nationwide uniform approach should be agreed upon and started for the recording of bat occurrences, so that the conservation status and the success of protection may be viewed more clearly. The agreement to establish and fund a federal bat monitoring needs to be assured (compare BFN 2003).

Moreover, the Federal Agency for Nature Conservation should make available the equipment developed and tested in the T&D project to be used in the field for bat conservation (compare DIETZ & WEBER 2002). Particularly the "Leaflet Series 1–9" should be available at all times and if necessary updated.

The federal states have the duty to inform the general public about house-dwelling bats through frequent media campaigns. This task is best carried out by a specialized and professionall coordination centre for bat conservation which can bring together the monitoring data (BIEDERMANN et al. 2003). State governments can promote campaigns in which the public authorities support both the security of bat roosts and the installation of new roosts in and on private and public buildings. Finally, it is highly recommended that federal states with Red Lists of threatened mammals which have last been updated before 1995 should update these.

Local government should perform all possible protection measures on public buildings and land owned by them. They should also maintain contact to bat specialists and competent authorities in order to support inquiries and initiatives of citizens professionally. Most suitable would be the establishment of a network of trained local bat conservation consultants who work closely together with conservation authorities and conservation organisations.

If local government or other authorities organize a recording of bats within their area of settlement, the following guidelines should be followed (including proof of qualification of those contracted to carry out the work):

- The goals of the surveys are:
  - Locating summer roosts, particularly maternity roosts;
  - Locating and classifying important foraging sites and flight paths;
  - Identifying which species of bat occur in the area;
  - Estimating colony sizes.
- Methods are:
  - Five inspection rounds in the months May–July with bat detectors in the hours before sunrise in order to register swarming bats.
  - Five inspection rounds in the months of May–June with bat detectors in the evening hours in order to locate roosts (animals flying out), flight routes and frequently used foraging sites.
  - Six net trappings (minimum of 3, total length of the net 80 m) in foraging sites (identification of species that are hard to find with detectors) in the months May–August.
  - Counts of emerging bats at known maternity roosts (if possible simultaniously to counts at neighbouring roosts) in the months May–July.
  - Three inspection rounds with bat detectors at night in order to locate roosts by the calls of young left in the roost (serotine bat) from the end of May–mid-July.
  - Nocturnal inspections of cowsheds.
  - If possible, net trapping at maternity roosts in the months May–June in order to fix telemetry transmitters to the captured females and thus find out more about the roost assemblage by radio-tracking these females in the following days.
  - Net trapping of *Myotis* species at maternity roosts to define the species.
- Content of the report should be:
  - Detailed description of the applied methods and the hours of inspection rounds.
  - Description of all roosts located.
  - Presentation on maps of all roosts, a potential roost assemblage, flight paths and foraging sites.
  - Suggestions for precise protection measures in the area of analysis.

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This project could not have been carried out without the unwavering enthusiasm towards this group of animals, the commitment and the expert knowledge of Peter Boye (Federal Agency for Nature Conservation). Not to go unmentioned is the contribution of Karl Kugelschafter (Wildlife Biology Gießen), who belongs to the original creative directors of the project and whose technical innovations made the nocturnal observation and recording of bats possible.

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14 References

ARBEITSGEMEINSCHAFT FÜR FLEDERMAUSSCHUTZ IN HESSEN (AGFH) (eds. 1994): Die Fledermäuse Hessens. – Verlag Manfred Hennecke, Remshalden-Buoch, 248 pp.

ARBEITSGEMEINSCHAFT FÜR FLEDERMAUSSCHUTZ IN HESSEN (AGFH) (eds. 2002): Die Fledermäuse Hessens II. Kartenband zu den Fledermausnachweisen von 1995–1999. – ottodruck, medien, design, Heppenheim/Bergstraße, 66 pp.

ALBRECHT, R. & BEKKER, R. (2001): MUNA III – Bunkeranlagen aus dem 2. Weltkrieg und der sowjetischen Besatzungszeit als Fledermausquartiere – gegenwärtige Situation und Perspektiven. – Nyctalus 7(6): 589-599.

ANON (1995): Biodiversity: Report of the UK steering group. – London.

ARLETTAZ, R. (1995): Ecology of the sibling mouse-eared bats (*Myotis myotis* and *Myotis blythii*): zoogeography, niche, competition and foraging. – Horus Publishers, Martigny, 222 pp.

ARLETTAZ, R. (1996): Ernährung und Jagdhabitatwahl beim Großen und Kleinen Mausohr. – Fledermaus-Anzeiger Extrablatt 1: 7-8.

AUDET, D. (1990): Foraging behavior and habitat use by a gleaning bat, *Myotis myotis* (Chiroptera: Vespertilionidae). – Journal of Mammalogy 71: 420-427.

AUDET, D. & FENTON, M. B. (1988): Heterothermy and the use of torpor by the bat *Eptesicus fuscus* (Chiroptera: Vespertilionidae): a field study. – Physiological Zoology 61(3): 197-204.

AVERY, M. I. (1986): Factors affecting the emergence times of Pipistrelle bats. – Journal of Zoology (London) 209: 293-296.

AVISE, J. C. (1989): Gene Trees and Organismal Histories: A Phylogenetic Approach to Population Biology. – Evolution 43(6): 1192-1208.

AVISE, J. C. (1994): Molecular Markers, Natural History and Evolution. – Chapman and Hall, New York.

BACHMANN, R. (1994): Breitflügelfledermaus, *Eptesicus serotinus* (Schreber, 1774). – Naturschutzreport 8: 81-84.

BARLOW, K. E. & JONES, G. (1999): Roosts, echolocation calls and wing morphology of two phonic types of *Pipistrellus pipistrellus*. – Zeitschrift für Säugetierkunde 64: 257-268.

BARRATT, E. M., DEAVILLE, R., BURLAND, T. M., BRUFORD, M. W., JONES, G., RACEY, P. A. & WAYNE, R. K. (1997): DNA answers the call of pipistrelle bat species. – Nature 387: 138-139.

BATTERSBY, J. E. (1999): A comparison of the roost ecology of the brown long-eared bat *Plecotus auritus* and the serotine bat *Eptesicus serotinus*. – University of Sussex, 202 pp.

BECK, A. (1991): Nahrungsuntersuchungen bei der Fransenfledermaus, *Myotis nattereri* (Kuhl, 1818). – Myotis 29: 67-70.

*BELLE, CHRISTINA (2001): Mikrogeographische Untersuchung von Wochenstubenkolonien der Breitflügelfledermaus *Eptesicus serotinus* (Schreber, 1774). – Diploma thesis, Philipps-University Marburg.

BUNDESAMT FÜR NATURSCHUTZ (BFN) (2003): Grundlagen für die Entwicklung eines Monitorings der Fledermäuse in Deutschland. – BfN-Skripten 73, Bonn, 142 pp.

BIEDERMANN, M. (1997): Das Artenhilfsprogramm Kleine Hufeisennase in Thüringen. – in: Tagungsband: "Zur Situation der Hufeisennasen in Europa" Nebra, den 26.–28. Mai 1995 (Arbeitskreis Fledermäuse Sachsen-Anhalt), IFA-Verlag: 27-32.

BIEDERMANN, M., MEYER, I. & BOYE, P. (2003): Bundesweites Bestandsmonitoring von Fledermäusen soll mit dem Mausohr beginnen. – Natur und Landschaft 78(3): 89-92.

BILO, M. (1990): Verhaltensbeobachtungen in einer Wochenstube des Mausohrs, *Myotis myotis* (Borkhausen, 1797). – Nyctalus 3(2): 99-118.

BINOT-HAFKE, M., GRUTTKE, H., LUDWIG, G. & RIECKEN, U. (2000): Bundesweite Rote Listen – Bilanzen, Konsequenzen, Perspektiven. – Schriftenreihe für Landschaftspflege und Naturschutz 65, Bonn, 255 pp.

BIRKY, C. W., JR. , FUERST, P. & MARUYAMA, T. (1989): Organelle gene diversity under migration, mutation, and drift: equilibrium expectations, approach to equilibrium, effects of heteroplasmic cells, and comparison to nuclear genes. – Genetics 121: 613-627.

BIRKY, C. W., JR., TAKEO, M & FUERST, P. (1983): An Approach to Population and Evolutionary Genetic Theory for genes in Mitochondria and Chloroplasts, and some Results. – Genetics 103: 513-527.

BLAB, J. (1980): Grundlagen für ein Fledermaus-Hilfsprogramm. – Kilda-Verlag, Greven, 44 pp.

BÖHME, W. & NATUSCHKE, G. (1967): Untersuchung der Jagdflugaktivität freilebender Fledermäuse in

Wochenstuben mit Hilfe einer doppelseitigen Lichtschranke und einige Ergebnisse an *Myotis myotis* (Borkhausen, 1797) und *Myotis nattereri* (Kuhl, 1818). – Säugetierkundliche Mitteilungen 15: 129-138.

BORKENHAGEN, P. (1993): Atlas der Säugetiere Schleswig-Holsteins. – Landesamt für Naturschutz und Landespflege, Kiel, 131 pp.

BOYD, I. & STEBBINGS, R. E. (1989): Population changes of brown long-eared bats (*Plecotus auritus*) in bat boxes at Thetford Forest. – Journal of Applied Ecology 26: 101-112.

BOYE, P. (2002): Projekte im Verbund für den Fledermausschutz – die Strategie des Bundesamtes für Naturschutz zur Umsetzung des EUROBATS-Abkommens. – Schriftenreihe für Landschaftspflege und Naturschutz 71: 279-288.

BOYE, P., DIETZ, M. & WEBER, M. (1999): Fledermäuse und Fledermausschutz in Deutschland – Bats and Bat Conservation in Germany. – Bundesamt für Naturschutz, Bonn, 112 pp.

BRIGHAM, R. M. (1991): Flexibility in foraging and roosting behaviour by the big brown bat (*Eptesicus fuscus*). – Canadian Journal of Zoology 69: 117-121.

BUCHEN, C. (1991): Verschieferung einer Hauswand mit Wochenstube der Fransenfledermaus (*Myotis nattereri*). – Nyctalus 4(1): 22-24.

BULLOCK, D. J., COMBES, B. A. & EALES, L. A. (1987): Analysis of the timing and pattern of emergence of the pipistrelle bat (*Pipistrellus pipistrellus*). – Journal of Zoology (London) 211: 267-274.

BURLAND, T. M., BARRATT, E. M., BEAUMONT, M. A. & RACEY, P. A. (1999): Population genetic structure and gene flow in a gleaning bat, *Plecotus auritus*. – Proceedings of the Royal Society of London Series B 266 (1422): 975-980.

BURLAND, T. M., BARRATT, E. M., NICHOLS, R. A. & RACEY, P. A. (2001): Mating patterns, relatedness and the basis of natal philopatry in the brown long-eared bat, *Plecotus auritus*. – Molecular Ecology 10: 1309 – 1321.

CASTELLA, V., RUEDI, M. & EXCOFFIER, L. (2001): Contrasted patterns of mitochondrial and nuclear structure among nursery colonies of the bat *Myotis myotis*. – Journal of Evolutionary Biology 14(5): 708-720.

CASTOR, T., DETTMER, K. & JÜPTNER, S. (1993): Vom Tagesmenü zum Gesamtfraßspektrum des Grauen Langohrs (*Plecotus austriacus*) – 2 Jahre Freilandarbeit für den Fledermausschutz. – Nyctalus 4 (5): 495-538.

CATTO, C. M. C., HUTSON, A. M., RACEY, P. A. & STEPHENSON, P. J. (1996): Foraging behaviour and habitat use of the serotine bat (*Eptesicus serotinus*) in southern England. – Journal of Zoology (London) 238: 623-633.

CERVEN_, J. & HORÁCEK, I. (1981): Comments on the life history of *Myotis nattereri* in Czechoslovakia. – Myotis 18-19: 156-162.

COPE, J. B., WHITAKER, J. O. & GUMMER, S. L. (1991): Duration of bat colonies in Indiana. – Proceedings of the Indiana Academy of Science 99: 199-201.

COTTERILL, F. P. D. & FERGUSSON, R. A. (1993): Capturing free-tailed bats (Chiroptera: Molossidae): the description of a new trapping device. – Journal of Zoology (London) 231: 645-651.

DE JONG, J. (1995): Habitat use and species richness of bats in a patchy landscape. – Acta Theriologica 40 (3): 237-248.

DE JONG, J. & AHLÉN, I. (1991): Factors affecting the distribution patterns of bats in Uppland, central Sweden. – Holarctic Ecology 14: 92-96.

DEGN, H. J. (1983): Field activity of a colony of Serotine Bats (*Eptesicus serotinus*). – Nyctalus 1 (6): 521-530.

DEGN, H. J. (1987): Summer activity of bats at a large hibernaculum. – in: European bat research 1987, Charles University Press, Praha, pp.: 523-526.

DESALLE, R., TEMPLETON, A. R., MORI, I., PLETSCHER, S. & JOHNSTON, J. S. (1987): Temporal and spatial heterogeneity of mtDNA polymorphisms in natural populations of *Drosophila mercatorum*. – Genetics 116: 215-223.

DIEHL, D. A. (1994): Untersuchungen zur Biologie der Breitflügelfledermaus in Hessen. – in: Die Fledermäuse Hessens (AGFH), Verlag Manfred Hennecke, Remshalden-Buoch, pp.: 128-132.

DIETERICH, J. D. & H. Dieterich (1988): Zur Ansiedlung von Waldfledermäusen in Schleswig-Holstein. – Myotis 26: 153-158.

DIETZ, M. & SIMON, M. (1999): Fledermausschutz und Fledermausforschung für gebäudebewohnende Fledermausarten – ein neues Erprobungs- und Entwicklungsvorhaben (E & E-) des Bundes. – Nyctalus 7 (1): 29-42.

DIETZ, M. & SIMON, M. (2003): Konzept zur Durchführung der Bestandserfassungund des Monitorings für Fledermäuse in FFH-Gebieten im Regierungsbezirk Gießen. – BfN-Skipten 73: 87-140.

DIETZ, M. & WEBER, M. (2000): Baubuch Fledermäuse – Eine Ideensammlung für fledermausgerechtes Bauen. – Gießen, 252 pp.

DIETZ, M. & WEBER, M. (2002): Von Fledermäusen und Menschen – Ergebnisse und Erfahrungen aus einem Modellvorhaben zum Schutz hausbewohnender Fledermäuse. – Bundesamt für Naturschutz, Bonn-Bad Godesberg, 197 pp.

*EICHHORN, MARCUS (1998): Populationsökologische Untersuchungen zur jahreszeitlichen Nutzungsdynamik an zwei großen Winterquartieren der Zwergfledermaus (*Pipistrellus pipistrellus* Schreber, 1774) in Nord-Hessen. – Diploma thesis, Philipps-University Marburg.

EICHSTÄDT, H. (1995): Ressourcennutzung und Nischengestaltung in einer Fledermausgemeinschaft im Nordosten Brandenburgs. – TU Dresden, pp.: 113.

EICHSTÄDT, H. & BASSUS, W. (1995): Untersuchungen zur Nahrungsökologie der Zwergfledermaus (*Pipistrellus pipistrellus*). – Nyctalus 5 (6): 561-584.

EISENTRAUT, M. (1960): Die Wanderwege der in der Mark Brandenburg beringten Mausohren. – Bonner zoologische Beiträge 11: 112-123.

*ENGEL, CHRISTIAN (2002): Eine Analyse von Jagdgebieten und Lebensraum der Mopsfledermaus (*Barbastella barbastellus*). – Diploma thesis, Philipps-University Marburg.

ENTWISTLE, A. C., RACEY, P. A. & SPEAKMAN, J. R. (1997): Roost selection by the brown long-eared bat *Plecotus auritus*. – Journal of Applied Ecology 34: 399-408.

ENTWISTLE, A. C., RACEY, P. A. & SPEAKMAN, J. R. (2000): Social and population structure of a gleaning bat, *Plecotus auritus*. – Journal of Zoology (London) 252: 11-17.

EXCOFFIER, L., SMOUSE, P. E. & QUATTRO, J. M. (1992): Analysis of molecular variance inferred from metric distances among DNA haplotypes: applications to human mitochondrial DNA restriction data. – Genetics 131: 479-491.

FELTEN, H. & KOCK, D. (1979): Fledermausbeobachtungen in Gebieten des südlichen West-Deutschlands 1945-1979. – Myotis 16: 3-82.

*FEYERABEND, FRANK (1998): Ökologische Untersuchungen verschiedener Aspekte der sommerlichen Aktivität der Zwergfledermaus (*Pipistrellus pipistrellus* Schreber, 1774). – Diploma thesis, Philipps-University Marburg.

FEYERABEND, F. & SIMON, M. (1998): Quartiernutzung und Quartierwechsel von Wochenstubenkolonien der Zwergfledermaus (*Pipistrellus pipistrellus*). – Zeitschrift für Säugetierkunde 63 (Sonderheft): 16-17.

FEYERABEND, F. & SIMON, M. (2000): Use of roosts and roost switching in a summer colony of 45 kHz phonic type pipistrelle bats (*Pipistrellus pipistrellus* Schreber, 1774). – Myotis 38: 51-59.

FISCHER, J. A. (1994a): Braunes Langohr – *Plecotus auritus* (Linnaeus, 1758). – Naturschutzreport 8: 94-97.

FISCHER, J. A. (1994b): Graues Langohr – *Plecotus austriacus* (Fischer, 1829). – Naturschutzreport 8: 101.

FLÜCKIGER, P. F. & BECK, A. (1995): Observations on the habitat use for hunting by *Plecotus austriacus* (Fischer, 1829). – Myotis 32-33: 121-122.

FRANK, H. (1960): Beobachtungen an Fledermäusen in Höhlen der Schwäbischen Alb unter besonderer Berücksichtigung der Mopsfledermaus (*Barbastella barbastellus*). – Bonner zoologische Beiträge 11 (Sonderheft): 143-149.

FRANK, H. (1971): Fledermausbeobachtung in Höhlen der Schwäbischen Alb in den Wintern 1965-1970. – Decheniana Beiheft 18: 95-97.

FRANK, R. & DIETZ, M. (1999): Fledermäuse im Lebensraum Wald. – Hessisches Ministerium für Umwelt, Landwirtschaft und Forsten, Merkblatt 37: 1-128.

FRANKE, K. (1997): Kleine Bartfledermaus (*Myotis mystacinus*) von Breitflügelfledermaus (*Eptesicus serotinus*) aus einem Flachkasten an einer Hauswand verdrängt. – Nyctalus 6(3): 229-232.

*FRIEDRICH, NATASCHA (2001): Ökologische Untersuchungen am Großen Mausohr *Myotis myotis* (Borkhausen, 1797) unter besonderer Berücksichtigung einer Jagdhabitatsanalyse in einer Mittelgebirgsregion. – Diploma thesis, Philipps-University Marburg.

FUHRMANN, M. (1994): Die Langohren (Gattung: *Plecotus*, Geoffrey 1818). – in: Die Fledermäuse Hessens (AGFH), Verlag Manfred Hennecke: 70-75.

FUHRMANN, M. & GODMANN, O. (1994): Baumhöhlenquartiere vom Braunen Langohr und von der Bechsteinfledermaus: Ergebnisse einer telemetrischen Untersuchung. – in: Die Fledermäuse Hessens. (AGFH), Verlag Manfred Hennecke, Remshalden-Buoch, pp.: 181-186.

GAISLER, J. (1979): Ecology of bats. – in: Ecology of small mammals (STODDARD, D.M.), Chapman & Hall, London, pp.: 281-342.

GAISLER, J. & HANÁK, V. (1969): Ergebnisse der zwanzigjährigen Beringung von Fledermäusen (Chiroptera) in der Tschechoslowakei: 1948 – 1967. – Acta Scientiarium Naturalis Brno 3 (5): 1-33.

GAISLER, J., ZUKAL, J., REHÁK, Z. & HOMOLKA, M. (1998): Habitat preference and flight activity of bats in a city. – Journal of Zoology (London) 244: 439-445.

GEBHARD, J. (1997): Unsere Fledermäuse. – Naturhistorisches Museum Basel, Basel, 72 pp.

GEBHARD, J. & OTT, M. (1985): Etho- ökologische Beobachtungen an einer Wochenstube von *Myotis myotis* (Borkh., 1797) bei Zwingen (Kanton Bern, Schweiz). – Mitteilungen der Naturforschenden Gesellschaft in Bern 1985: 129-144.

GEISLER, H. & DIETZ, M. (1999): Zur Nahrungsökologie einer Wochenstubenkolonie der Fransenfledermaus (*Myotis nattereri* Kuhl, 1818) in Mittelhessen. – Nyctalus 7 (1): 87-101.

GERELL, R. & LUNDBERG, K. (1985): Social organization in the bat *Pipistrellus pipistrellus*. – Behavioral Ecology and Sociobiology 16 (16): 177-184.

GLAS, G. H. (1981): Activities of serotine bats (*Eptesicus serotinus*) in a nursing-roost. – Myotis 18-19: 164-167.

GODMANN, O. (1994): Zwergfledermaus, *Pipistrellus pipistrellus* (Schreber 1774). – in: Die Fledermäuse Hessens (AGFH), Verlag Manfred Hennecke, Remshalden-Buoch, pp.: 248.

GODMANN, O. (1995): Beobachtungen eines Wochenstubenquartiers der Kleinen Bartfledermaus. – Natur und Museum 125: 26-29.

GODMANN, O. (1996): Vorkommen und Schutzproblematik der Zwergfledermaus (*Pipistrellus pipistrellus*) im Rheingau-Taunus-Kreis und Wiesbaden. – Jahrbücher des Nassauischen Vereins für Naturkunde 117: 69-80.

GODMANN, O. & RACKOW, W. (1995): Invasionen der Zwergfledermaus (*Pipistrellus pipistrellus* (Schreber1774) in verschiedenen Gebieten Deutschlands. – Nyctalus 5 (5): 395-408.

GOTTSCHALK, C. (2000): Aufenthaltsorte und Verhaltensweisen von Fledermäusen mit Rückschlüssen auf die postglaziale Ausbreitung der Chiropteren. – Nyctalus 7 (3): 291-297.

GRIMMBERGER, E. (1979): Untersuchungen über den Einfluß klimatischer Faktoren auf das Verhalten der Zwergfledermaus, *Pipistrellus pipistrellus* (Schreber 1774), im Winterquartier und während der sogenannten Invasionen. – Nyctalus 1 (2): 145-157.

GRIMMBERGER, E. (1983): Beitrag zum Verhalten der Zwergfledermaus, *Pipistrellus pipistrellus* (Schreber 1774). – Nyctalus 1 (6): 553-571.

GRIMMBERGER, E. & BORK, H. (1978a): Untersuchungen zur Biologie, Ökologie und Populationsdynamik der Zwergfledermaus, *Pipistrellus p. pipistrellus* (Schreber 1774), in einer großen Population im Norden der DDR, Teil 1. – Nyctalus 1 (1): 55-73.

GRIMMBERGER, E. & BORK, H. (1978b): Untersuchungen zur Biologie, Ökologie und Populationsdynamik der Zwergfledermaus, *Pipistrellus p. pipistrellus* (Schreber 1774), in einer großen Population im Norden der DDR, Teil 2. – Nyctalus 1 (2): 122-136.

GRUMMT, J. & HAENSEL, J. (1966): Zum Problem der "Invasionen" von Zwergfledermäusen, *Pipistrellus p. pipistrellus* (Schreber, 1774). – Zeitschrift für Säugetierkunde 31: 382-390.

GÜTTINGER, R. (1997): Jagdhabitate des Großen Mausohrs (*Myotis myotis*) in der modernen Kulturlandschaft. – Bundesamt für Umwelt, Wald und Landschaft (BUWAL), Schriftenreihe Umwelt Nr. 288, Wien, pp.: 140.

GÜTTINGER, R., ZAHN, A., KRAPP, F. & SCHOBER, W. (2001): *Myotis myotis*. – in: Handbuch der Säugetiere Europas, Band 4/I, Fledertiere 1. (KRAPP, F.), AULA-Verlag, Wiebelsheim, pp.: 123-207.

HAENSEL, J. (1974): Über die Beziehungen zwischen verschiedenen Quartiertypen des Mausohrs, *Myotis myotis* (Borkhausen 1797), in den brandenburgischen Bezirken der DDR. – Milu 3: 542-603.

HAENSEL, J. (1990): Über die Anwesenheit adulter Männchen in Wochenstubengesellschaften des Mausohrs (*Myotis myotis*). – Nyctalus 3 (3): 208-220.

HAENSEL, J. (1992): In den Ostberliner Stadtbezirken nachgewiesene Fledermäuse – Abschlußbericht, insbesondere den Zeitraum 1980-1991betreffend. – Nyctalus 4 (4): 379-427.

HAENSEL, J. (1994): Zum Eintritt der Geschlechtsreife bei der Breitflügelfledermaus (*Eptesicus serotinus*) und zum Aufenthalt adulter Männchen in ihren Wochenstubengesellschaften. – Nyctalus 5 (2): 181-184.

HAMILTON, I. M. & BARCLAY, R. M. R. R. (1994): Patterns of daily torpor and day-roost selection by male and female big brown bats (*Eptesicus fuscus*). – Canadian Journal of Zoology 72 (4): 744-749.

HANDTKE, K. (1967): Zum Vorkommen der Langohrfledermäuse *Plecotus auritus* L. und *Plecotus austriacus* Fischer im Nordharz und seinem Vorland. – Hercynia 4 (3): 359-367.

HARBUSCH, C. (1996): Fledermausschutz im Saarland. – Nyctalus 6 (1): 48-51.

HARRISON, R. G. (1989): Animal mitochondrial DNA as a genetic marker in population and evolutionary biology. – Trends in Ecology and Evolution 4: 6-11.

HARTL, D. L. & CLARK, A. G. (1997): Principles of Population Genetics. – Sinauer, Sunderland, MA., 542 pp.

HAVEKOST, H. (1960): Die Beringung der Breitflügelfledermaus (*Eptesicus serotinus*) im Oldenburger Land. – Bonner Zoologische Beiträge, Sonderheft 11: 222-233.

HECK, K. & BARZ, J. (2000): Die Nutzung zweier Autobahnbrücken in Nordhessen durch das Mausohr (*Myotis myotis*) und Beobachtungen zur Störungstoleranz. – Nyctalus 7 (3): 298-309.

HECKENROTH, H., POTT, B. & WIELERT, S. (1988): Zur Verbreitung der Fledermäuse in Niedersachsen. – Naturschutz Landschaftspflege Niedersachsen 17: 5-32.

HEDDERGOTT, M. (1992a): Beschreibung eines Wochenstubenquartiers der Mopsfledermaus (*Barbastella barbastellus*) nebst Bemerkungen zur Verbreitung im Eichsfeld. – Nyctalus 4 (4): 372-378.

HEDDERGOTT, M. (1992b): Zur Bestandsentwicklung des Mausohrs (*Myotis myotis*) in den Wochenstuben des Eichsfelds/Thüringen. – Nyctalus 4 (3): 281-292.

HEDDERGOTT, M. (1994): Verbreitung und Bestandsentwicklung des Mausohrs, *Myotis myotis* (Borkhausen, 1797), in Nordthüringen. – Nyctalus 5 (3/4): 277-291.

HEIDINGER, F., VOGEL, S. & METZNER, W. (1989): Thermoregulatory behaviour in a maternity colony of *Myotis myotis*. – in: European Bat Research 1987 (HANAK, V., HORÁČEK, I. & GAISLER, J.), Charles University Press, Prague, pp.: 189-190.

HEISE, G. (1983): Ergebnisse sechsjähriger Untersuchungen mittels Fledermauskästen im Kreis Prenzlau, Uckermark. – Nyctalus 1 (6): 504-512.

HEISE, G. (1989): Ergebnisse reproduktionsbiologischer Untersuchungen am Abendsegler (*Nyctalus noctula*) in der Umgebung von Prenzlau/Uckermark. – Nyctalus 3: 17-32.

HEISE, G. & SCHMIDT, A. (1988): Beiträge zur sozialen Organisation und Ökologie des Braunen Langohrs (*Plecotus auritus*). – Nyctalus 2: 445-465.

HENKEL, F., TRESS, C. & TRESS, H. (1982): Zum Bestandsrückgang der Mausohren (*Myotis myotis*) in Südthüringen. – Nyctalus 1 (4/5): 453-471.

HERMANNS, U. & POMMERANZ, H. (1999): Fledermausquartiere an Plattenbauten, ihre Gefährdung und Möglichkeiten ihrer Erhaltung und Neuschaffung. – Nyctalus 7 (1): 3-16.

*HERZMANN, JANA (1998): Untersuchungen zur Beschaffenheit von Wochenstubenquartieren der Zwergfledermaus (*Pipistrellus pipistrellus* Schreber, 1774). – Gradvate thesis, Justus-Liebig-University Gießen.

HIEBSCH, H. (1983): Faunistische Kartierung der Fledermäuse in der DDR, Teil 1. – Nyctalus 1(6): 489-503.

HIEBSCH, H. & HEIDECKE, D. (1987): Faunistische Kartierung der Fledermäuse in der DDR. – Nyctalus 2 (3/4): 213-246.

HOEHL, E. (1960): Beringungsergebnisse in einem Winterquartier der Mopsfledermaus (*Barbastella barbastellus* Schreb.) in Fulda. – Bonner zoologische Beiträge 11 (Sonderheft): 192-197.

HOLZHAIDER, J. & ZAHN, A. (2001): Bats in the Bavarian Alps: species composition and utilization of higher altitudes in summer. – Zeitschrift für Säugetierkunde 66: 144-154.

HORÁCEK, I. (1981): Comparative notes on the population structure in several European bat species. – Myotis 18-19: 48-53.

HORÁ_EK, I. (1985): Population ecology of *Myotis myotis* in central Bohemia (Mammalia: Chiroptera). – Acta Univ. Carolinae – Biologica 1981 (VIII): 161-267.

HOYING, K. M. & KUNZ, T. H. (1998): Variation in size at birth and post-natal growth in the insectivorous bat *Pipistrellus subflavus* (Chiroptera: Vespertilionidae). – Journal of Zoology (London) 245: 15-27.

*HÜTTENBÜGEL, SANDRA (1998): Untersuchungen zur Populationsstruktur der Zwergfledermaus (*Pipistrellus pipistrellus* Schreber, 1774) mittels genetischer und feldökologischer Methoden. – Diploma thesis, Philipps-University Marburg.

HTTP://WWW.EUROBATS.ORG (2003): Nationaler Bericht zum Fledermausschutz in der Bundesrepublik Deutschland 2000-2003. – link: National Reports, Germany 2003.

HUMMITZSCHE, E. (1960): Fledermausberingung in Leipzig und Umgebung. – Bonner zoologische Beiträge 11, Sonderheft: 99-104.

HURKA, L. (1966): Beitrag zur Bionomie, Ökologie und zur Biometrik der Zwergfledermaus (*Pipistrellus pipistrellus* Schreber, 1774) (Mammalia: Chiroptera) nach den Beobachtungen in Westböhmen. – Vestník Ceskoslovenské spolecnosti zoologické 30 (3): 228-246.

*HUXOL, MARTINA (1999): Untersuchungen zur Ökologie der Breitflügelfledermaus *Eptesicus serotinus* (Schreber, 1774) unter besonderer Berücksichtigung des Quartierwechselverhaltens. – Diploma thesis, Philipps-University Marburg.

ILLI, A. (1999): Untersuchungen zur Jagdhabitatwahl, Raumnutzung und Aktivität von Fransenfledermäusen, *Myotis nattereri* (Kuhl, 1817). – Zoologisches Museum der Universität Zürich.

ISSEL, B., ISSEL, W. & MASTALLER, M. (1977): Zur Verbreitung und Lebensweise der Fledermäuse in Bayern. – Myotis 15: 19-97.

*JANTSCHKE, SABINE (2002): Ist die Verbreitung der Fransenfledermaus (*Myotis nattereri*) strukturabhängig? Eine landschaftsökologische Lebensraumanalyse. – Diploma thesis, Philipps-University Marburg.

JANSEN, E. A. (1993): Fledermauskartierung 1992 in Kassel mit Detektoren. – Nyctalus 4 (6): 587-620.

JENKINS, E. V., LAINE, T., MORGAN, S. E., COLE, K. R. & SPEAKMAN, J. R. (1998): Roost selection in the pipistrelle bat, *Pipistrellus pipistrellus* (Chiroptera: Vespertilionidae), in northeast Scotland. – Animal Behaviour 56: 909-917.

JONES, G., ALTRINGHAM, J. D. & DEATON, R. (1996): Distribution and population densities of seven species of bat in northern England. – Journal of Zoology (London) 240: 788-798.

JONES, G. & VAN PARIJS, S. M. (1993): Bimodal echolocation in pipistrelle bats: are cryptic species present? – Proceedings of the Royal Society of London, Series B – Biological Sciences 251: 119-125.

JUNQUEIRA, L. C. & CARNEIRO, J. (1986): Histologie. – Springer Verlag, Berlin, Heidelberg, New York, 669 pp.

KALKO, E. K. V. (1991): Das Echoortuungs- und Jagdverhalten der drei europäischen Zwergfledermausarten, *Pipistrellus pipistrellus* (Schreber 1774), *Pipistrellus nathusii* (Keyserling & Blasius 1939) und *Pipistrellus kuhli* (Kuhl 1819). – Universität Tübingen, 310 pp.

KALLASCH, C. (1994): Möglichkeiten der Telemetrierung bei der Bestandserfassung von Fledermäusen. – Nyctalus 5 (3/4): 297-301.

KALLASCH, C. & LEHNERT, M. (1994a): Breitflügelfledermaus, *Eptesicus serotinus* (Schreber, 1774). – in: Die Fledermäuse Hessens (AGFH), Verlag Manfred Hennecke, Remshaleden-Buoch, pp: 60-61.

KALLASCH, C. & LEHNERT, M. (1994b): Fransenfledermaus, *Myotis nattereri* (Kuhl 1818). – in: Die Fledermäuse Hessens (AGFH), Verlag Manfred Hennecke, Remshalden-Buoch, pp.: 46-47.

KALLASCH, C. & LEHNERT, M. (1994c): Kleine Bartfledermaus, *Myotis mystacinus* (Kuhl 1819) und Große Bartfledermaus, *Myotis brandti* (Eversmann 1845). – in: Die Fledermäuse Hessens (AGFH), Verlag Manfred Hennecke: 40-45.

KERTH, G. & KÖNIG, B. (1999): Fission, fusion and nonrandom associations in female Bechstein's bats (*Myotis bechsteinii*). – Behaviour 136: 1187-1202.

KERTH, G., MAYER, F. & KÖNIG, B. (2000): Mitochondrial DNA (mtDNA) reveals that female Bechstein's bats live in closed societies. – Molecular Ecology 9 (6): 793-800.

KERTH, G., SAFI, K. & KONIG, B. (2002): Mean colony relatedness is a poor predictor of colony structure and female philopatry in the communally breeding Bechstein's bat (*Myotis bechsteinii*). – Behavioral Ecology and Sociobiology 52 (3): 203-210.

KIEFER, A., SCHREIBER, C. & VEITH, M. (1994): Netzfänge in einem unterirdischen Fledermausquartier in der Eifel (BRD, Rheinland-Pfalz) – Phänologie, Populationsschätzung, Verhalten. – Nyctalus 5 (3/4): 302-318.

KIEFER, A., SCHREIBER, C. & VEITH, M. (1996): Felsüberwinternde Fledermäuse (Mammalia, Chiroptera) im Regierungsbezirk Koblenz (BRD, Rheinland-Pfalz) – Vergleich zweier Kartierungsperioden. – Fauna und Flora in Rheinland-Pfalz Beiheft 21: 5-34.

KIEFER, A. & VEITH, M. (1998): Saisonale thermoregulatorische Hangplatzwahl in einem Sommer- und Winterquartier beim Grauen Langohr, *Plecotus austriacus* (Fischer, 1829) (Chiroptera, Vespertilionidae) – Posterbeitrag. – Nyctalus 6 (5): 532.

KLAUSING, O. (1988): Die Naturräume Hessens. – Schriftenreihe des Bayerischen Landesamtes für Umweltschutz 67: 19-27.

KLAWITTER, J. (1986): Bestandsentwicklung, Gefährdung und Schutz der Fledermäuse in Berlin (West). – Berliner Naturschutzblätter 30: 74-85.

KOCH, C. (1865): Das Wesentliche der Chiropteren mit besonderer Beschreibung der in dem Herzogthum Nassau und in den angrenzenden Landestheilen vorkommenden Fledermäuse. – Jahrbücher des Nassauischen Vereins für Naturkunde 17/18: 261-593.

KOCK, D. & ALTMANN, J. (1994): Mopsfledermaus, *Barbastella barbastellus* (Schreber 1774). – in: Die Fledermäuse Hessens (AGFH), Verlag Manfred Hennecke, Remshalden-Buoch, pp.: 76-77.

KOETTNITZ, J. & HEUSER, R. (1994): Fledermäuse in großen Autobahnbrücken Hessens. – in: Die Fledermäuse Hessens. (AGFH), Verlag Manfred Hennecke, Remshalden-Buoch, pp.: 171-180.

KÖNIG, H. & KÖNIG, W. (1995): Ergebnisse einer Untersuchung nistkastenbewohnender Fledermäuse in der Nordpfalz. – Nyctalus 5 (6): 529-544.

KRAUS, M. & GAUCKLER, A. (1972): Zur Verbreitung und Ökologie der Bartfledermaus *Myotis brandti* (Eversmann 1845) und *Myotis mystacinus* (Kuhl 1819) in Süddeutschland. – Laicher Höhlenfreund 13: 23-31.

KREISAUSSCHUSS DES LANDKREISES MARBURG-BIEDENKOPF (Hrsg. 1996): Der Landkreis Marburg-Biedenkopf. – Hausdruckerei der Kreisverwaltung, Marburg.

KUGELSCHAFTER, K. & HARRJE, C. (1996): Die Levensauer Brücke bei Kiel als Massenüberwinterungsquartier für Große Abendsegler (*Nyctalus noctula*). – Zeitschrift für Säugetierkunde 61, Sonderheft: 33-34.

KUGELSCHAFTER, K., HORVATH, T., KIMPEL, W., STEFFNY, G. & VOLK, T. (1995): Neue Techniken zur Überwachung von Fledermäusen. – in: Methoden feldökologischer Säugetierforschung (STUBBE, M. STUBBE, A. & D. HEIDECKE), Martin-Luther-Universität Halle-Wittenberg, pp.: 373-382.

KULZER, E. (1989): Fledermäuse im Ökosystem Wald. – Veröff. Naturschutz und Lanschaftspflege Bad.-Württ. 64-65: 203-220.

KULZER, E., BASTIAN, H.W. & FIEDLER, M. (1987): Fledermäuse in Baden-Württemberg. – Beih. Veröff. Naturschutz Landschaftspflege Bad.-Württ. 50: 1-152.

KUNZ, T. H. (1982): Ecology of Bats. – Plenum, New York, 425 pp.

LABES, R. (1990): Zur Fledermausfauna der Insel Usedom. – Nyctalus 3 (3): 237-247.

LABES, R. & KÖHLER, W. (1987): Zum Vorkommen der Fledermäuse im Bezirk Schwerin – ein Beitrag zu Fledermausforschung und -schutz. – Nyctalus 2 (3/4): 285-308.

LANG, A. J. (1996): A long-term study of a pipistrelle colony in Sutton, Surrey, from 1985 to 1994. – The London Naturalist 75: 75-80.

LAUFENS, G. (1973): Einfluss der Aussentemperaturen auf die Aktivitätsperiodik der Fransen- und Bechsteinfledermäuse (*Myotis nattereri*, Kuhl 1818 und *Myotis bechsteini*, Leisler 1818). – Periodicum Biologorum 75: 145-152.

LESINSKI, G., FUSZARA, E. & KOWALSKI, M. (2000): Foraging areas and relative density of bats (Chiroptera) in differently human transformed landscapes. – Zeitschrift für Säugetierkunde 65: 129-137.

LEWIS, S. E. (1995): Roost fidelity of bats: a review. – Journal of Mammalogy 76 (2): 481-496.

LIEGL, A. & HELVERSEN, O. V. (1987): Jagdgebiet eines Mausohrs (*Myotis myotis*) weitab von der Wochenstube. – Myotis 25: 71-76.

LIMPENS, H. J. G. A. & BONGERS, W. (1991): Bats in dutch forests. – Myotis 29: 129-136.

LIMPENS, H. J. G. A. & KAPTEYN, K. (1991): Bats, their behaviour and linear landscape elements. – Myotis 29: 39-48.

LIMPENS, H., MOSTERT, K. & BONGERS, W. (Hrsg. 1997): Atlas van de Nederlandse vleermuizen – Onderzoek naar verspreiding en ecologie. – Stichting Uitgeverij van de Koninklijke Nederlandse Natuurhistorische Vereniging, Utrecht, 260 pp.

LIMPENS, H. & ROSCHEN, A. (1996): Bausteine einer systematischen Fledermauserfassung Teil 1 – Grundlagen. – Nyctalus 6 (1): 52-60.

MAIER, C. (1992): Activity patterns of pipistrelle bats (*Pipistrellus pipistrellus*) in Oxfordshire. – Journal of Zoology (London) 228: 69-80.

MAINER, W. (1991): Zum Vorkommen der Fledermäuse im Kreis Werdau. – Nyctalus 4 (2): 168-180.

MANTEL, N. (1967): The detection of disease clustering and a generalized regression approach. – Cancer Research 27: 209-220.

*MANWIRE, DANIEL (2000): Ethoökologische Untersuchungen zum sommerlichen Quartierwechselverhalten der Zwergfledermaus (*Pipistrellus pipistrellus* Schreber, 1774, Phonotyp 45 kHz). – Diploma thesis, Philipps-University Marburg.

MAYER, F., PETIT, E. & HELVERSEN, O. V. (2002): Genetische Strukturierung von Populationen des Abendseglers (*Nyctalus noctula*) in Europa. – Schriftenreihe für Landschaftspflege und Naturschutz 71: 267-278.

MESCHEDE, A. & HELLER, K.-G. (2000): Ökologie und Schutz von Fledermäusen in Wäldern. – Schriftenreihe für Landschaftspflege und Naturschutz 66, Bonn, 374 pp.

MITCHELL-JONES, A. J., AMORI, G., BOGDANOWICZ, W., KRY_TUFEK, B., REIJNDERS, P. J. H., SPITZENBERGER, F., STUBBE, M., THISSEN, J. B. M., VOHRALÍK, V. & ZIMA, J. (1999): The Atlas of European Mammals. – Poyser Natural History, London, 484 pp.

MOTHES-WAGNER, U. (1992): Charakterisierung des Landkreises Marburg-Biedenkopf. – in: Die Vogelwelt des Landkreises Marburg-Biedenkopf (HGON, Arbeitskreis Marburg-Biedenkopf, Kreisausschuß des Landkreises Marburg-Biedenkopf), Selbstverlag der HGON, AK Marburg-Biedenkopf, pp.: 1-79.

MÜLLER, E. (1993): Fledermäuse in Baden-Württemberg II. – Beih. Veröff. Naturschutz Landschaftspflege Bad.-Württ. 75: 9-96.

MULLIS, K. B. & FALOONA, F. A. (1987): Specific synthesis of DNA in vitro via a polymerase chain reaction. – Methods of Enzymology 155: 335-350.

NAGEL, A. & NAGEL, R. (1988): Einsatz von Fledermauskästen zur Ansiedlung von Fledermäusen: ein Vergleich von zwei verschiedenen Gebieten Baden-Württembergs. – Myotis 26: 129-144.

NATUSCHKE, G. (1960): Ergebnisse der Fledermausberingung und biologische Beobachtungen an Fledermäusen in der Oberlausitz. – Bonner Zoologische Beiträge 11, Sonderheft: 77-98.

NEUWEILER, G. (1993): Biologie der Fledermäuse. – Georg Thieme Verlag, Stuttgart, New York, 350 pp.

NYHOLM, E. S. (1965): Zur Ökologie von *Myotis mystacinus* (Leisl.) und *M. daubentoni* (Leisl.) (Chiroptera). – Annales Zoologici Fennici 2: 77-123.

OAKELEY, S. F. & JONES, G. (1998): Habitat around maternity roosts of the 55 kHz phonic type of pipistrelle bats (*Pipistrellus pipistrellus*). – Journal of Zoology (London) 245: 222-228.

OHLENDORF, B. (1982): Beobachtungen an einer Wochenstube der Kleinen Bartfledermaus (*Myotis mystacinus*) in Stecklenberg/Harz. – Nyctalus 1 (4/3): 476-477.

OHLENDORF, B. (1983): Die Zwergfledermaus, *Pipistrellus pipistrellus* (Schreber 1774), ein Faunenelement des Harzes. – Nyctalus 1 (6): 587-593.

OLDENBURG, W. & HACKETHAL, H. (1989): Zur Bestandsentwicklung und Migration des Mausohrs, *Myotis myotis* (Borkhausen, 1797) (Chiroptera: Vespertilionidae), in Mecklenburg. – Nyctalus 2 (6): 501-519.

PANDURSKA, R. (1998): Reproductive behaviour and conservation status of nursery colonies of *Myotis myotis* (Borkhausen, 1797) in Bulgaria. – Myotis 36: 143-150.

PARK, K. J., MASTERS, E. & ALTRINGHAM, J. D. (1998): Social structure of three sympatric bat species (Vespertilionidae). – Journal of Zoology (London) 244: 379-389.

PEREZ, J. L. & IBA_EZ, C. (1991): Preliminary results on acitvity rythms and space use obtained by radiotracking a colony of *Eptesicus serotinus*. – Myotis 29: 61-65.

PETIT, E. (1998): Population structure and post-glacial history of the noctule bat *Nyctalus noctula* (Chiroptera, Mammalia). – PhD thesis, Friedrich-Alexander-University, Erlangen-Nürnberg.

PETIT, E., EXCOFFIER, L. & MAYER, F. (1999): No evidence of bottleneck in the postglacial recolonization of Europe by the noctule bat (*Nyctalus noctula*). – Evolution 53 (4): 1247-1258.

PETIT, E. & MAYER, F. (2000): A population genetic analysis of migration: the case of the noctule bat (*Nyctalus noctula*). – Molecular Ecology 9 (6): 683-690.

PETRI, B., PAABO, S., VON HAESELER, A. & TAUTZ, D. (1997): Paternity assessment and population subdivision in a natural population of the larger mouse-eared bat *Myotis myotis*. – Molecular Ecology 6 (3): 235-242.

PIECHOCKI, R. (1966): Über die Nachweise der Langohr -Fledermäuse *Plecotus auritus* L. und *Plecotus austriacus* Fischer im mitteldeutschen Raum. – Aus dem Zool. Institut d. Martin-Luther-Uni. Halle-Wittenberg: 407-415.

PIEPER, H. (1971): Weitere zehn Jahre (1961-1970) Fledermausberingung im Raum Fulda. – Beiträge zur Naturkunde in Osthessen 4: 39-48.

PLETSCH, A. (1989): Hessen. – Wissenschaftliche Buchgesellschaft, Darmstadt.

POCHA, S. (1999): Fransenfledermaus – *Myotis nattereri* (Kuhl, 1817). – Materialien zu Naturschutz und Landschaftpflege 1999: 22-24.

PODANY, M. (1995): Nachweis einer Baumhöhlenwochenstube der Mopsfledermaus (*Barbastella barbastellus*) sowie einige Anmerkungen zum Überwinterungsverhalten im Flachland. – Nyctalus 5 (5): 473-479.

PRIM, R. C. (1957): Shortest connection networks and some generalizations. – Bell Syst. Technol. J. 36: 1389-1401.

PRITCHARD, S. & MURPHY, F. (1988): A Highland bat survey 1986-87: Glen Lyon and Rannoch. – Batchat 10: 9-14.

RACEY, P. A. (1969): Diagnosis of pregnancy and experimental extension of gestation in the pipistrelle bat, *Pipistrellus pipistrellus*. – Journal of Reproduction and Fertility 19: 465-474.

RACEY, P. A. (1973): Environmental factors affecting the length of gestation in heterothermic bats. – Journal of Reprocuction and Fertility Suppl. 19: 175-189.

RACEY, P. A. (1974): Ageing and assessment of reproductive status of Pipistrelle bats, *Pipistrellus pipistrellus*. – Journal of Zoology (London) 173: 264-271.

RACEY, P. A. & SWIFT, S. M. (1981): Variations in gestation length in a colony of pipistrelle bats (*Pipistrellus pipistrellus*) from year to year. – Journal of Reproduction and Fertility 61: 123-129.

RACEY, P. A. & SWIFT, S. M. (1985): Feeding ecology of *Pipistrellus pipistrellus* (Chiroptera: Vespertilionidae) during pregnancy and lactation. I. Foraging behaviour. – Journal of Animal Ecology 54: 205-215.

RACKOW, W. (1994): Quartierbeschreibungen der Nord- und Zwergfledermaus (*Eptesicus nilssoni* bzw. *Pipistrellus pipistrellus*) im Südharz. – Nyctalus 5 (3-4): 336-337.

RACKOW, W. (2002): Invasionsartiger Einflug von Zwergfledermäusen, *Pipistrellus pipistrellus* (Schreber, 1774) zu ungewöhnlicher Jahreszeit. – Nyctalus 8 (2): 182-186.

RACKOW, W. & GODMANN, O. (1996): Weitere Beobachtungen zum Invasionsverhalten der Zwergfledermaus (*Pipistrellus pipistrellus* Schreber, 1774). – Nyctalus 6 (1): 61-64.

*RHIEL, SILVIA (2000): Ökologische Untersuchungen zur zeitlichen und räumlichen Quartiernutzung sowie zur nächtlichen Aktivität des Großen Mausohrs *Myotis myotis* (Borkhausen, 1797). – Diploma thesis, Philipps-University Marburg.

RICHARZ, K. (1989): Ein neuer Wochenstubennachweis der Mopsfledermaus *Barbastella barbastellus* (Schreber, 1774) in Bayern mit Bemerkungen zu Wochenstubenfunden in der BRD und DDR sowie zu Wintervorkommen und Schutzmöglichkeiten. – Myotis 27: 71-80.

RICHARZ, K. (1993): Fledermausschutz an Gebäuden. – Zeitschrift für Vogelkunde und Naturschutz in Hessen – Vogel und Umwelt 7: 293-305.

RICHARZ, K. (1994): Die Fledermäuse Deutschlands. Eine Kurzbeschreibung. – in: Die Fledermäuse Hessens (AGFH), Verlag Manfred Hennecke, Remshalden-Buoch, pp: 21-31.

RICHARZ, K. & LIMBRUNNER, A. (1999): Fledermäuse – fliegende Kobolde der Nacht. – Kosmos-Verlag, Stuttgart.

RINDLE, U. & ZAHN, A. (1997): Untersuchungen zum Nahrungsspektrum der Kleinen Bartfledermaus (*Myotis mystacinus*). – Nyctalus 6 (3): 304-308.

ROBINSON, M. F. & STEBBINGS, R. E. (1993): Food of the serotine bat, *Eptesicus serotinus* – is faecal analysis a valid qualitative and quantitative technique? – Journal of Zoology (London) 231: 239-248.

ROBINSON, M. F. & STEBBINGS, R. E. (1997): Home range and habitat use by the serotine bat, *Eptesicus serotinus*, in England. – Journal of Zoology (London) 243: 117-136.

ROCHE, N. & ELLIOTT, P. (2000): Analysis of bat (*Pipistrellus* and *Myotis* spp.) activity in deciduous woodlands in England using a nonlinear model. – Myotis 38: 19-40.

ROER, H. (1979): 1180 Zwergfledermäuse (*Pipistrellus pipistrellus* Schreber) in Entlüftungsrohren eines Gebäudes verendet. – Myotis 17: 31-40.

ROER, H. (1988): Beitrag zur Aktivitätsperiodik und zum Quartierwechsel der Mausohrfledermaus *Myotis myotis* (Borkhausen, 1797) während der Wochenstubenperiode. – Myotis 26: 97-107.

ROGÉE, E. & LEHMANN, G. (1994a): Beobachtungen zur Biologie und Ursachen der Jungtiersterblichkeit beim Großen Mausohr in Nordhessen. – in: Die Fledermäuse Hessens. (AGFH), Verlag Manfred Hennecke, Remshalden-Buoch, pp: 121-127.

ROGÉE, E. & LEHMANN, G. (1994b): Großes Mausohr, *Myotis myotis* (Borkhausen 1797). – in: Die Fledermäuse Hessens (AGFH), Verlag Manfred Hennecke, Remshalden-Buoch, pp: 50-51.

ROSSITER, S. J., JONES, G., RANSOME, R. D. & BARRATT, E. M. (2000): Genetic variation and population structure in the endangered greater horseshoe bat *Rhinolophus ferrumequinum*. – Molecular Ecology 9: 1131 – 1135.

RUDOLPH, B.-U. & LIEGL, A. (1990): Sommerverbreitung und Siedlungsdichte des Mausohrs *Myotis myotis* in Nordbayern. – Myotis 28: 19-38.

RYBERG, O. (1947): Studies on bats and bat parasites. – Bokvörlaget Svensk Natur, Stockholm, 330 pp.

RYDELL, J., BUSHBY, A., COSGROVE, C. C. & RACEY, P. A. (1994): Habitat use by bats along rivers in north east Scotland. – Folia Zoologica (Brno) 43: 417-424.

SACHTELEBEN, J. (1991): Zum "Invasions"verhalten der Zwergfledermaus (*Pipistrellus pipistrellus*). – Nyctalus 4 (1): 51-66.

SCHÄFER, H. (1998): Untersuchungen zur Quartiersituation des Großen Mausohrs, *Myotis myotis* (Borkhausen 1797), in Hessen. – Gradvate thesis, Justus-Liebig-University Gießen.

SCHMIDT, A. (1980): Zum Vorkommen der Fledermäuse im Süden des Bezirks Frankfurt/O. – Nyctalus 1 (3): 209-226.

SCHMIDT, C. & MAINER, W. (1999): Breitflügelfledermaus – *Eptesicus serotinus* (Schreber, 1774). – Materialien zu Naturschutz und Landschaftspflege 1999: 41-43.

SCHNEIDER, S., ROESSLI, D. & EXCOFFIER, L. (2000): A software package for population genetics. – Genetics and Biometry Lab, Department of Anthropology.

SCHNITTLER, M., LUDWIG, G., PRETSCHER, P. & BOYE, P. (1994): Konzeption der Roten Listen der in Deutschland gefährdeten Tier- und Pflanzenarten unter Berücksichtigung der neuen internationalen Kategorien. – Natur und Landschaft 69: 451-459.

SCHOBER, W. (1999): Graues Langohr – *Plecotus austriacus* (Fischer, 1829). – Materialien zu Naturschutz und Landschaftspflege 1999: 48-50.

SCHOBER, W. & GRIMMBERGER, E. (1998): Die Fledermäuse Europas. – Franckh-Kosmos Verlag, Stuttgart, 265 pp.

SCHULZE, W. (1992): Wie reagierten Mausohren (*Myotis myotis*) auf eine totale Dachsanierung im Rathaus Sangerhausen. – Nyctalus 4 (3): 323-324.

SCHWARTING, H. (1994): Erfahrungen mit Fledermauskästen in einer hessischen Region. – in: Die Fledermäuse Hessens (AGFH), Verlag Manfred Hennecke, Remshalden-Buoch, pp.: 159-166.

*SCHWEIZER, SANDRA (2000): Beobachtungen zum Winterschlafverhalten der Zwergfledermaus (*Pipistrellus pipistrellus* Schreber, 1774) im Marburger Schloßkeller. – Diploma thesis, Justus-Liebig-University Gießen.

*SENDOR, THOMAS (1997): Populationsökologische Untersuchungen zu Quartiernutzungsstrategien der Zwergfledermaus (*Pipistrellus pipistrellus* Schreber, 1774) mit Schwerpunkt auf einem ganzjährig genutzten "Winterquartier". – Diploma thesis, Philipps-University Marburg.

SENDOR, T. (2002): Population ecology of the pipistrelle bat (*Pipistrellus pipistrellus* Schreber, 1774): the significance of the year-round use of hibernacula for life histories. – PhD thesis, Philipps-University Marburg, 148 S.

SENDOR, T. & SIMON, M. (2000): Schätzung der Populationsgröße am Winterquartier schwärmender Zwergfledermäuse (*Pipistrellus pipistrellus*): ein Methodenvergleich. – Beiträge zur Ökologie 4 (2): 43-52.

SIEMERS, B. M., KAIPF, I. & SCHNITZLER, H.-U. (1999): The use of day roosts and foraging grounds by Natterer's bats (*Myotis nattereri* Kuhl, 1818) from a colony in southern Germany. – Zeitschrift für Säugetierkunde 64: 241-245.

SIEMERS, B. M. & SCHNITZLER, H.-U. (1999): Natterer's bat (*Myotis nattereri*, Kuhl, 1818) hawks for prey close to vegetation using echolocation signals of very broad bandwidth. – Behavioral Ecology and Sociobiology 47/2000: 400-412.

SIERRO, A. (1999): Habitat selection by barbastelle bats (*Barbastella barbastellus*) in the Swiss Alps (Valais). – Journal of Zoology (London) 248: 429-432.

SIMON, M. & KUGELSCHAFTER, K. (1996): Zur saisonalen Nutzungsdynamik eines Zwergfledermaus-Winterquartiers (*Pipistrellus pipistrellus*). – Zeitschrift für Säugetierkunde 61 (Sonderheft): 57-58.

SIMON, M. & KUGELSCHAFTER, K. (1999): Die Ansprüche der Zwergfledermaus (*Pipistrellus pipistrellus*) an ihr Winterquartier. – Nyctalus 7: 102-111.

SLATKIN, M. (1987): Gene flow and the geographic structure of natural populations. – Science 236: 787 – 792.

SMIT-VIERGUTZ, J. & SIMON, M. (2000): Eine vergleichende Analyse des sommerlichen Schwärmverhaltens der Zwergfledermaus (45 kHz Ruftyp, *Pipistrellus pipistrellus* Schreber, 1774) an den Invasionsorten und am Winterquartier. – Myotis 38: 69-89.

SMOUSE, P. E., LONG, J. C. & SOKAL, R. R. (1986): Multiple regression and correlation extensions of the Mantel Test of matrix correspondence. – Systematic Zoology 35: 627-632.

SPEAKMAN, J. R. (1993): Clustering in the emergence behavior of bats: some pitfalls in the analysis of bat emergence patterns and how to overcome them. – Bat Research News 34: 49-54.

Speakman, J. R., Bullock, D. J., Eales, L. A. & Racey, P. A. (1992): A problem defining temporal pattern in animal behaviour: clustering in emergence behaviour of bats from maternity roosts. – Animal Behaviour 43: 491-500.

Speakman, J. R., Irwin, N., Tallach, N. & Stone, R. (1999): Effect of roost size on the emergence behaviour of pipistrelle bats. – Animal Behaviour 58: 787-795.

Speakman, J. R., Racey, P. A., Catto, C. M. C., Webb, P. I., Swift, S. M. & Burnett, A. M. (1991): Minimum summer populations and densities of bats in N.E. Scotland, near the northern borders of their distribution. – Journal of Zoology (London) 225: 327-345.

Speakman, J. R., Stone, R. E. & Kerslake, J. E. (1995): Temporal patterns in the emergence behavior of pipistrelle bats, *Pipistrellus pipistrellus*, from maternity colonies are consistent with an anti-predator response. – Animal Behaviour 50 (5): 1147-1156.

Spitzenberger, F. (1993): Die Mopsfledermaus (*Barbastella barbastellus* SCHREBER 1774) in Österreich. Mammalia austriaca 20. – Myotis 31: 111-153

Stebbings, R. E. & Griffith, F. (1986): Distribution and status of bats in Europe. – Institute of Terrestrial Ecology, Huntingdon, 142 pp.

Steinhauser, D. (2002): Untersuchungen zur Ökologie der Mopsfledermaus, *Barbastella barbastellus* (Schreber, 1774) und der Bechsteinfledermaus, *Myotis bechsteinii* (Kuhl, 1817) im Süden des Landes Brandenburg. – Schriftenreihe für Landschaftspflege und Naturschutz 71: 81-98.

Stratmann, B. (1979): Untersuchungen über die historische und gegenwärtige Verbreitung der Fledermäuse im Bezirk Halle (Saale) nebst Angaben zur Ökologie, Teil 1. – Nyctalus 1 (2): 97-121.

Stratmann, B. (1980): Untersuchungen über die historische und gegenwärtige Verbreitung der Fledermäuse im Bezirk Halle (Saale) nebst Angaben zur Ökologie, Teil 2. – Nyctalus 1 (3): 177-186.

Stutz, H. P. & Haffner, M. (1985): Wochenstuben und Sommerquartiere der Zwergfledermaus *Pipistrellus pipistrellus* (Schreber, 1774) (Mammalia: Chiroptera) in der Schweiz. – Jahresbericht der Naturforschenden Gesellschaft Graubünden 102: 129-135.

Swift, S. M. (1980): Activity patterns of pipistrelle bats (*Pipistrellus pipistrellus*) in north-east Scotland. – Journal of Zoology (London) 190: 285-295.

Swift, S. M. (1997): Roosting and foraging behaviour of Natterer's bats (*Myotis nattereri*) close to the northern border of their distribution. – Journal of Zoology (London) 242: 375-384.

Syring, S. (2000): Anteil reproduzierender Weibchen in Wochenstubengesellschaften des Großen Mausohrs (*Myotis myotis*, Borkhausen 1797) – vergleichende Studie an verschiedenen Wochenstubenquartieren. – University Gesamthochschule Kassel: 74 pp.

Taake, K.-H. (1984): Strukturelle Unterschiede zwischen den Sommerhabitaten von Kleiner und Großer Bartfledermaus (*Myotis mystacinus* und *M. brandti*) in Westfalen. – Nyctalus 2: 16-32.

Taake, K.-H. (1992): Strategien der Ressourcennutzung an Waldgewässern jagender Fledermäuse (Chiroptera: Vespertilionidae). – Myotis 30: 7-74.

Tajima, F. (1983): Evolutionary relationship of DNA sequences in finite populations. – Genetics 105 (3): 437-460.

Takahata, N. & Palumbi, S. R. (1985): Extranuclear differentiation and gene flow in the finite island model. – Genetics 109: 441-457.

Thompson, M. J. A. (1977): The pipistrelle bat (*Pipistrellus pipistrellus*) in and around York. – Naturalist 102: 109-116.

Thompson, M. J. A. (1979): The whiskered bat (*Myotis mystacinus*) and Brandt´s bat (*Myotis brandti*) in Yorkshire – an historical perspective. – Naturalist 104: 147-154.

Thompson, M. J. A. (1987): Longevity and survival of female pipistrelle bats (*Pipistrellus pipistrellus*) on the Vale of York, England. – Journal of Zoology (London) 211: 209-214.

Thompson, M. J. A. (1990): The pipistrelle bat *Pipistrellus pipistrellus* Schreber on the Vale of York. – Naturalist 115: 41-56.

Thompson, M. J. A. (1992): Roost philopatry in female pipistrelle bats, *Pipistrellus pipistrellus*. – Journal of Zoology (London) 228: 673-679.

Topál, G. (2001): *Myotis nattereri* (Kuhl, 1818) – Fransenfledermaus. – in: Handbuch der Säugetiere Europas, Band 4/I, Fledertiere 1. (Krapp, F.), AULA-Verlag, Wiebelsheim, pp.: 405-442.

Trappmann, C. (1996): Fledermauschutz und Fledermausforschung in Münster – eine Analyse der bisherigen Ergebnisse und Methoden nach 8 Jahren. – Nyctalus 6 (1): 3-20.

Trappmann, C. & Clemen, G. (2000/2001): Beobachtungen zur Nutzung des Jagdgebiets der Fransenfledermaus *Myotis nattereri* (Kuhl, 1817) mittels Telemetrie. – Acta Biol. Benrodis 11: 1-31.

TRESS, C. (1994): Zwergfledermaus *Pipistrellus pipistrellus* (Schreber, 1774). – Naturschutzreport 8: 90-97.

TRESS, C., FISCHER, J. A., WELSCH, K.-P., FIRNAU, F., HENKEL, F. & TREß, J. (1988): Zur Bestandssituation der Fledermäuse Südthüringens. Teil 1. – Veröffentlichungen des Naturhistorischen Museum Schleusingen 3: 92-97.

TYPINIE, Y. & AELLEN, V. (2001): *Myotis mystacinus* (Kuhl, 1818) – Kleine Bartfledermaus. – in: Handbuch der Säugetiere Europas, Band 4/I, Fledertiere 1. (KRAPP, F.), AULA-Verlag, Wiebelsheim, pp.: 321-344.

TUTTLE, M. D. (1974): An improved trap for bats. – Journal of Mammalogy 55 (2): 475-477.

TUTTLE, M. D. (1976): Population ecology of the gray bat (*Myotis grisescens*): factors influencing growth and survival of newly volant young. – Ecology 57: 587-595.

TUTTLE, M. D. & STEVENSON, D. E. (1982): Growth and survival of bats. – in: Ecology of Bats (KUNZ, T. H.), Plenum Press, Lonon, New York, pp.: 105-150.

UNRUH, M. (2001): Zum Kenntnisstand der Fledermausfauna im östlichen Burgenlandkreis (Sachsen-Anhalt) unter besonderer Berücksichtigung gebäudebewohnender Arten. – Nyctalus 7 (6): 619-631.

VAUGHAN, N., JONES, G. & HARRIS, S. (1997): Habitat use by bats (Chiroptera) assessed by means of a broad-band acoustic method. – Journal of Applied Ecology 34: 716-730.

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WALSH, A. L. & MAYLE, B. A. (1991): Bat activity in different habitats in a mixed lowland woodland. – Myotis 29: 97-104.

WEIDNER, H. (1994): Fransenfledermaus – *Myotis nattereri* (Kuhl, 1817). – Naturschutzreport 8: 56-59.

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WELSCH, K.-P. (1994): Kleine Bartfledermaus – *Myotis mystacinus* (Kuhl, 1819). – Naturschutzreport 8: 70-73.

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WILHELM, M. (1971): Zum Ausflugs- und Wanderverhalten der Zwergfledermaus (*Pipistrellus pipistrellus*). – Nyctalus 3: 65-67.

WILKINSON, G. S. & FLEMING, T. H. (1996): Migration and evolution of lesser long-nosed bats *Leptonycteris curasoae*, inferred from mitochondrial DNA. – Molecular Ecology 5 (3): 329-339.

WILSON, A. C., CANN, R. L., CARR, S. M., GEORGE, M., GYLLENSTEN, U. B., HELM-BYCHOWSKI, K. M., HIGUCHI, R. G., PALUMBI, S. R., PRAGER, E. M., SAGE, R. D. & STONEKING, M. (1985): Mitochondrial DNA and two perspectives on evolutionary genetics. – Linnean Society of London 26: 375-400.

WINCHELL, J. M. & KUNZ, T. H. (1996): Day-roosting activity budgets of the eastern pipistrelle bat, *Pipistrellus subflavus* (Chiroptera: Vespertilionidae). – Canadian Journal of Zoology 74 (3): 431-441.

WOLZ, I. (1986): Wochenstuben-Quartierwechsel bei der Bechsteinfledermaus. – Zeitschrift für Säugetierkunde 51: 65-74.

WORTHINGTON WILMER, J. & BARRATT, E. (1996): A non-lethal method of tissue sampling for genetic studies of chiropterans. – Bat Research News 37 (1): 1-3.

WRIGHT, S. (1965): The interpretation of population structure by F-statistics with special regards to systems of mating. – Evolution 19: 395-420.

ZAHN, A. (1995): Populationsbiologische Untersuchungen am Großen Mausohr (*Myotis myotis*). – PhD thesis, Ludwig-Maximilians University.

ZAHN, A. (1998): Individual migration between colonies of Greater mouse-eared bats (*Myotis myotis*) in Upper Bavaria. – Zeitschrift für Säugetierkunde 63: 321-328.

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ZAHN, A. & KRÜGER-BARVELS, K. (1996): Wälder als Jagdhabitate von Fledermäusen. – Zeitschrift für Ökologie und Naturschutz 5 (2): 77-84.

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