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Kaarina

Centre for Economic Development, Transport and the Environment

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In 2007, the study was led by Emma Kosonen with Thomas Lilley. Biology students Pia Winberg and Pipsa Lappalainen worked as principal assistants. Elias Aarnio supported the Nature IT project conducted by Turku University of Applied Sciences, which managed the video surveillance of the bat house from May until August 2007. Temperature and humidity measurements were headed by Rauli Lautkankare from the Degree Programme of Civil Engineering at Turku University of Applied Sciences. The project was funded in 2007 by Turku University of Applied Sciences, the city of Kaarina and the Centre for Economic Development, Transport and the Environment of Southwest Finland.

1 PROJECT BACKGROUND

1.1 THE BAT HOUSE AND EARLIER OBSERVATIONS

In Kaarina, Southwest Finland, there is a traditional, two-storey wooden house. The ceiling spaces of the house have been a roost of a maternity colony of the northern bat for at least the last 30 years. The bat house is located in the centre of Kaarina, in an area that is intended, according to the confirmed town plan for the southern sector of the centre, for the construction of blocks of flats. Until August 2007, the house was used by Social Services of the City of Kaarina. In August of that year, these activities were moved elsewhere and the house was abandoned.

Pregnant northern bat females gather at the bat house at the turn of May–June and give birth to their young around Midsummer. At the turn of July-August, the bats leave the roost once the young bats are able to fly. During the summers of 2004 and 2005, approximately 15 adult individuals were counted at the house, and the number had increased by summer 2006 to a maximum of 21 adult northern bat individuals. Every year, several young are born and grow up in the house.

The colony has been monitored with a surveillance camera since June 2004 (Lappalainen & Aarnio 2004). The surveillance data has provided a wealth of new information on the life of the northern bat maternity colony. The bats have also been observed both visually and with the use of bat detectors.

Bats living in the bat house have been banded since 2005. Altogether 44 individuals (27 adults and 17 weanlings) have been banded. All adults have been females, and of the banded young, ten are female and seven male. Of the banded females, eight have been recaptured after their initial banding. This indicates that at least some of the females return to the bat house year after year. For example, female individual number 233, “Beata”, who was banded during the summer of 2005, was recaptured in the summer of 2007 for the third time.

In the summer of 2006, the movements of the bats in the bat house were tracked for the first time using radio transmitters. This was also the first time when radio-tracking was used in Finland as a method for studying northern bats. Eight northern bat females carried radio transmitters. In this study we found out the daily activities and foraging areas of the bats. Furthermore, it showed where at least some individuals of the bat house colony had moved once their young had learned to fly. (Kosonen & Lilley 2006)

1.2 ECOLOGY OF THE NORTHERN BAT

Considering their size, bats have long lifespans, with many species living for several decades. They reproduce slowly; most species give birth to only one pup each year. Bats use the same roosts and foraging areas from one year to the next as long as there are no significant changes to them (Schober & Grimmberger 1997). In Finland, bats feed on insects and other arthropods, which they catch at night with the help of echolocation (Lappalainen 2002).

PHOTO 1. *Northern bat. © Markku Lappalainen*

Based on current knowledge, the northern bat, *Eptesicus nilssonii* (Keyserling & Blasius, 1839), is Finland's most common and widely spread bat species, and they are found as far north as the 69º latitude (Kaikusalo 1993). It is one of the few bat species that has adapted to the low insect density found in hemiboreal coniferous forests (de Jong 1994). Usually, the northern bat prefers a wooded rural landscape, but it can also be found quite commonly in city centres. The northern bat is a fast flyer that generally hunts in clearings, along roads, or in logging areas or yards (Lappalainen 2002). It has been observed avoiding wide treeless spaces, such as industrial areas (Rydell 1992).

Along with the rest of Fennoscandia, Finland is the core area for the distribution of the northern bat, and therefore Finland also carries a great responsibility for the conservation of the species. The northern bat can also be found in Central and Eastern Europe (Schober & Grimmberger 1997). In Sweden, the northern bat has likely increased in numbers over the past decades (Ahlén 1998). On the other hand in Germany, for example, the species is threatened and in Austria, endangered. (Schober & Grimmberger 1997). The northern bat is quite adaptable; it has the ability to, among other things, take advantage of the insect swarms attracted to the streetlights in late spring and early autumn – times when insect abundance elsewhere is low (Rydell 1991, 1992). The highest age recorded for the northern bat is 14.5 years (Schober & Grimmberger 1997).

Jens Rydell has studied the reproductive and foraging ecology of northern bats in his home country of Sweden during the 1980s and 1990s. During the period of five summer seasons, Rydell's study in southern Sweden (57º latitude) noted that the bats were loyal to certain locations. There was no observed shift of individuals from one neighbouring colony to another. Only one unbanded adult (apparently from elsewhere) was captured in the colony following the initial trapping of the colony in question in 1982. Two other reproducing colonies located 800 and 1100 metres away from the studied colony were checked each year, but no banded females were found in those colonies. (Rydell 1989c)

Rydell (1989c) noted that the first bats arrived at the maternity colonies under observation around the turn of May-June (May 18 – June 8). The pups were born at the turn of June-July (June 29 – July 11) and the first young appeared outside of the colony approximately 15–17 days later (July 15–26). The bats left the area at the end of July or the beginning of August.

In Sweden, the roosts of the northern bats are generally located in heated buildings (Rydell 1986, 1989b). In the study mentioned above, the bats used four heated buildings as their roosts, and completely avoided the abandoned buildings in the same area. They changed their roost 1–4 times during the summer for a total of 14 times over the five summers recorded for research. The colony was disturbed twice for trapping, but there were no other observable reasons for the changes. The primary roost, which was used for over 71% of the research period, was on the ceiling near the chimney in an old wooden house. (Rydell 1989c)

In Rydell's study, the bats foraged every evening first in the area around the roost, after which they spread out towards the open farmland. Generally the bats remain in one area for several minutes before moving on to the next. Within Rydell's study (1989c), approximately 700 observations were made of the bats feeding in approximately 25 different feeding places, of which 80% were located within a 400-metre distance from the roost, and the rest within 1200 metres.

Along the 59º latitude in central Sweden, Johnny de Jong studied a reproducing colony of northern bats during the summers of 1989 and 1990. As long as the insect abundance was high, the bats fed close to their roost. Often, all of the individuals foraged within 200 metres from their roost. During the nursing period, the female bats must remain in the vicinity of the roost, since the newborn pups require warmth and food regularly. De Jong's research found, however, that during the second summer of the study the females made longer (4–5 kilometres) foraging flights, even though the pups were still unable to fly. The summer in question was rather cold, rainy and windy, so the insect abundance was low. (de Jong 1994)

In his study in Ulricehamn, Sweden, Rydell noted that the bats fed every evening if the temperature was above 10°C, but never if the temperature dropped below 6°C. When the temperature was 6–10°C, the feeding activity depended on the strength of the wind. In heavy rains at temperatures under 10°C, no bats left their roost to feed, but light rain and fog did not affect the feeding activity. The bats fed in the evenings, when the density of insects per cubic metre was at 0.1 or higher. This threshold value was exceeded any evening when the temperature was 10°C, but only occasionally on colder evenings. (Rydell 1989a.)

Many European bat species are in decline to some extent. Certain species have already become extinct in some countries. The reasons for this include a reduction in suitable roosts, the loss of feeding areas and increased use of pesticides in agriculture and building protection as well as prejudice against bats that results from ignorance (Eurobats 2008). In Great Britain, one of the largest threats to the conservation of the bat population is the disappearance of suitable roosts (Entwistle et al. 1997). Roosts offer bats shelter from the weather conditions and predators as well as provide a place for social interaction. In temperate climates, lack of shelter may be the critical factor for the survival of the bats (Humphrey 1975), so it is clear that a safe and sufficiently warm roost is a vital necessity for bats living at Finnish latitudes.

1.3 PROTECTION STATUS

All of the bat species found in Finland have been protected since 1923 (Nature Conservation Act 71/1923). Today, all of the current bat species found in the country are protected under Section 38 of the current Nature Conservation Act (Luonnonsuojelulaki 1096/1996). Bats also belong to the species listed in Annex IV (a) of the EU Council Directive (92/43/EEC) on the conservation of natural habitats and of wild fauna and flora. In accordance with Section 49 of the Nature Conservation Act (Luonnonsuojelulaki 1096/1996), for example, the destruction and deterioration of bat breeding sites and resting places is prohibited.

In 1991, the EUROBATS agreement protecting European bats was signed in London. Finland was a party to this agreement. The agreement entered into force on 20 October 1999 (Valtiosopimus 943/1999). The agreement binds the European countries to increasing bat research and protection, and to improving, in particular, information about poorly known species (Osara 2000). Currently, the most significant problem for bat conservation in Finland is that we do not have enough information to be able to present substantiated assessments regarding the population sizes and ideal level of protection for different species.

2 AIMS OF THE STUDY

This study sought to find answers to the following questions:

1. How does the movements and the daily activity of the northern bats fluctuate during the summer? In what sort of places do the bats forage?
2. Are there other roosts nearby the bat house in Kaarina suitable for the maternity colony of northern bats?
3. Are bat boxes appropriate roosts for northern bats?
4. How could the threats to bats caused by construction be reduced?

The study served as a pilot for a potential broader project which would aim to take bats more into consideration in land use planning and building. The objective for the future could be to develop practical solutions for building renovations and new buildings, which would facilitate the peaceful coexistence of bats and people.

Radio-tracking was used as a method for studying bats in Finland for the first time in 2006. This study confirmed, as presented in the summer of 2006, that radio-tracking is well-suited to northern bat research in Finnish conditions. The abundant publicity received as a result of the project assisted in spreading a positive image of bats in a variety of media outlets.

3 STUDYING METHODS AND PROJECT IMPLEMENTATION

3.1 RADIO-TRACKING

Methods

The study was primarily based on radio-tracking data. Bats were captured and individuals were selected for the study. Each bat had to be sufficiently heavy, in other words healthy, in order to be able to carry the radio transmitter without causing an unreasonable hindrance. Only adult bats were selected for tracking. Any captured bats not already banded were banded for future identification purposes.

PHOTO 2. *A banded northern bat. © Markku Lappalainen*

An area of about 0.25 cm² of fur was shaved from the back of the bats, and using surgical glue (Torbot Bonding Cement), a radio transmitter (Holohil Systems Ltd, model LB-2) weighing approximately half a gram was attached to the spot. The bats were then released and their movements were tracked each night with the help of a receiver (Biotrack Sika radio-tracking receiver) and antenna (Biotrack Yagi antenna) until sufficient data was collected, the transmitter stopped working or the bat succeeded in removing it.

PHOTO 3. *The fur on the bat's back is shortened in preparation for attaching the transmitter. © Markku Lappalainen*

PHOTO 4. *A radio transmitter is attached to the northern bat's back. © Markku Lappalainen*

PHOTO 5. *The radio-tracking receiver, the antenna and the bat detector. © Emma Kosonen*

TABLE 1. *The northern bat females that carried radio transmitters in 2006 and 2007 (bats from 2007 bolded). The control dates indicate dates when banded bats were caught again at the bat house. Weight and wing length are from dates when the bats were given the transmitters.*

Ring No.	"Name"	Banding Date	Control Date	2. Control Date	Wing (mm)	Weight (g)
604	Alma	13.6.2005	5.6.2006		39.4	11.95
233	**Beata**	13.6.2005	5.6.2006	3.6.2007	40.0	9.95
628	Camilla	4.6.2006	19.7.2006		43.1	11.75
605	Diana	13.6.2005	19.7.2006		39.7	11.25
524	Elizabeth	19.7.2006			40.10	10.75
231	Freija	13.6.2005	27.7.2006		40.9	12.00
630	Greta	27.7.2006			40.30	11.25
249	**Hilma**	27.7.2006	3.6.2007	31.5.2010	40.1	9.50
536	**Impi**	10.6.2007			39.60	10.55
641	**Justiina**	10.6.2007			41.70	11.25
230	**Kaisa**	13.6.2005	10.6.2007		40.2	12.75
537	**Liisi**	16.7.2007			40.90	10.95
643	**Maija**	16.7.2007			41.10	10.90
644	**Naima**	16.7.2007			39.60	10.60

Implementation

The tracking was completed over two separate periods, the first in early June 2007 and the second during the second half of July 2007. Eight northern bat females were carrying transmitters. Of these, seven produced comparable data. The researcher and the assistant followed their "own" assigned bats. The bats were followed on foot or by car, with the aim of retaining visual contact with the flying bat. An antenna was attached to the roof of the car in case the bat disappeared completely. In these cases, the researcher searched for the bat by driving around those areas in which the bats are known to forage. The plan was for one researcher to drive the car while another listened to the signal through headphones. Fortunately, it was unnecessary to resort to this method during the summer of 2007.

The fieldwork began at the beginning of May 2007. The study area was assessed during the day, and at night, the flying bats were sought using bat detectors. Experience from 2006 helped considerably in planning the fieldwork for 2007. The first bats were observed by the surveillance camera at the bat house on 22 May 2007, the very same day as in 2006. In the next evening, at least 12 bats left the house. The main group of bats arrived in 2007 about one and a half weeks earlier than in the year before, which may be the result of warmer weather near the end of May.

It was not possible to capture all of the individuals in the bat house, and in order to minimise the disturbance, these efforts were immediately discontinued as soon as the necessary number of individuals needed for the radio-tracking had been captured. The first capture was carried out on 3 June 2007. The yield of the capture was three individuals, of which one was banded and two, which had been banded in 2006, received a radio transmitter. The previous summer's approach of naming the bats that carried transmitters was continued in order to facilitate communication. The recaptured bats were Beata, ring number 233, which had been banded in the summer of 2005, and Hilma, ring number 249, which had been banded in 2006. Both females were already carrying transmitters during 2006.

In Finland, bats must not be captured or disturbed even for study purposes during the period of 15 June – 15 July, when the females are in the final stages of gestation, or are nursing their young (Kyheröinen & Stjernberg 2005). Since the tracking of Beata and Hilma succeeded and data was collected over a period of five nights, it was possible to carry out a second capture prior to the strict protection period for bats. Again, three bats were captured and transmitters were attached to all three. Of these, ring number 230, Kaisa, had been banded in 2005. The two other bats were banded on this capture. The bat with the ring number 536 was named Impi and 641 Justiina. Impi was tracked for six nights, Justiina for five and Kaisa for three.

The next bats were captured on 16 July, as the video images (see below in 3.2) indicated that the pups were already quite large. This third capture produced six individuals, of which three females were given a transmitter to carry. The three others were weanlings, two females and one male. The females selected for radio-tracking had all been nursing during the summer. They were named Liisi (ring number 537), Maija (643) and Naima (644). Liisi was tracked for six nights and Naima for five. Maija's movements did not provide any data, since the transmitter had fallen off prior to the day when the tracking was initiated.

After the third capture, the bats could no longer be captured from the bat house, because the colony left the building. The bats moved to the roof structures of a terraced house on Tuulikinkatu, located approximately 490 metres from the bat house. Radio-tracking was completed on 23 July. On 24 July, approximately 20 northern bats departed from Tuulikinkatu and, therefore, there is reason to assume that the majority of the bat house colony had moved there. All of the transmitter signals were located to the terraced house. Poor weather conditions forced the delay of the capture for Tuulikinkatu. The capture was attempted on 28 July, when only 1–3 bats emerged from the house. The attempt was unsuccessful and contact with the northern bats of the bat house was thus lost in 2007.

The largest number of adult females was counted on 19 June 2007, when 21 bats departed from the bat house between 23:34–00:19.

The radio-tracking study was interesting and challenging. The experiences with radio-tracking from summer 2006 helped to predict the movements of the bats, and the tracking technique was considered to have been highly successful. The hilly landscape in Kaarina, the dense population and, in particular, Kuusistonsalmi strait pose difficulties in trying to keep up with fast flying bats. The durability of the transmitters was good, despite their small size, lasting as long as 21 days. Unfortunately, the bats often succeeded in removing the transmitters too quickly.

3.2 OTHER STUDYING METHODS

The northern bat colony was monitored using a surveillance camera positioned in the attic of the house. The camera surveillance worked using an infrared light and the images were stored onto a computer. Additionally, ultrasound detectors or bat detectors (Pettersson D 240X) that convert the echolocation ultrasound signals to audible frequencies were also used as observation equipment.

4 RESULTS AND DISCUSSION

4.1 THE MOVEMENTS AND THE DAILY ACTIVITY OF THE NORTHERN BATS DURING SUMMER

The first studied question was to clarify the fluctuations in the northern bats' movements and 24-hour activity over the summer. Furthermore, the study focused on the types of places which the bats chose for foraging.

Already at the beginning of the summer, the bats of the bat house colony fed notably far from the house; this was contrary to, for example, Rydell's studies in Sweden, which are presented in Chapter 1.2 of this report. For example, the Munkkeholma spit favoured by many of the bats is located about 2.4 kilometres from the bat house.

It is difficult to say whether the number of insects was exceptionally low and therefore the bats flew further away in search of food. In July, the insect density was apparently sufficient, but the bats' foraging flights remained quite lengthy in both 2006 and 2007. This study confirmed information gained during the summer of 2006: the bats particularly preferred the wooded, undeveloped hills on the city centre or on its borders as well Kuusistonsalmi strait as important feeding areas.

The locations of the radio-tracked bats as well as places mentioned in the text can be found in the maps 1–3 in the Appendix.

Foraging areas

The northern bats of the bat house often began their foraging in the centre of Kaarina. The undeveloped wooded areas of the city centre were particularly favoured. One interesting detail is Beata's choice to forage for 45 minutes over the central square of asphalt and cement on 7 June. She also defended her feeding territory and drove away another bat that intruded at the same site. Generally, however, bats prefer areas that are covered with vegetation.

The small hills of the city centre are close by, and they apparently provide a significant foraging area for the bats prior to their moving on to the primary foraging areas. The city centre is an important foraging area primarily because it is close to the house. The foraging areas in the city centre enable the bats to return quickly to the house for rest, safety or nurse their young. The microclimate

of city centres can be as much as several degrees warmer than the surrounding countryside (Roth et al. 1989), predators are few and competition with other bat species is practically nonexistent. At the end of the summer and in the autumn, the streetlights attract insects, of which the northern bats can take advantage.

The radio-tracked bats, with the exception of Kaisa, began their foraging in the centre of Kaarina every night, and then moved on to the northern or southern shorelines of Kuusistonsalmi strait, in most cases to the area east from Rauhalinnansaari islet. It was typical for several different individuals to return to approximately the same place along the shores of the strait night after night.

As fast flyers the northern bats were able to fly from the house to the northern shoreline of Kuusisto in a few minutes. An abundant number of northern bats' favoured insects, such as chironomids, mosquitoes and caddis flies swarmed around the reed beds along the shores. The water evened out the temperature differences. On colder nights, when there would be less food available for the bats elsewhere, there was still a great deal of insect activity above the water. In addition to northern bats, only one Daubenton's bat (*Myotis daubentonii*) was observed along the shores of Kuusistonsalmi strait, so there was very little competition between different bat species for the food available in the area.

There was no particular change in the foraging areas between the beginning and end of the summer. On the other hand at the end of the summer in 2007, only two bats were radio-tracked, so the data from those observations cannot be used to make any grand conclusions. Liisi (2007) and Freija (2006) were the two individuals which flied farthest and commuted the longest distances. They both were radio-tracked in the late summer. There is, however, no means of knowing whether these females made long foraging flights for food also during the early summer. In Sweden, the radio-tracking study conducted by de Jong (1994) indicated, however, that the northern bat females remained closer to the colony in early summer and made longer foraging flights towards the end of the summer.

Flight times

The time that bats spent outside of their roost varied in the early summer from zero to 198 minutes. When calculating in minutes, Beata and Hilma flew almost the same amount; Beata's average over five nights was 169 minutes and Hilma's 190. Impi was radio-tracked during a more variable period in terms of the weather, and was recorded spending two of the six radio-tracked nights completely indoors and, on the third night, only fed for 74 minutes. Justiina, which carried a radio transmitter during the same period, was outdoors for 138 minutes when Impi stayed indoors. On the second night, Justiina did not emerge at all.

In late summer, Liisi, which was tracked for six nights, was in flight for a minimum of 133 minutes and a maximum of 249. Naima spent from 82 to 196 minutes outdoors over the five nights of radio-tracking. On two nights, Naima took short breaks of 10 and 16 minutes in the roost. Liisi did not take any breaks during one night, and the breaks that she took on other nights lasted from 26 to 122 minutes. An exception to this was the night of tracking when she took flight at 23:04, returned at 00:27, rested for 16 minutes and took flight again at 00:43. Liisi returned at 1:50 to rest for only 22 minutes and went out once again at 2:12. That time she stayed out hunting until 3:30 and returned under quite heavy rain conditions. Using the shortest possible routes Liisi's flight distance, on that night alone, totalled approximately 14 kilometres. In reality, the distance was probably a lot longer. It is difficult to determine the reasons for the differences between the bats. It may be that their pups were in different stages of development, and, therefore they required different degrees of care. There may also have been differences in the condition of the mothers, even though there were no notable differences in their weight at the time they were captured.

The bats were often observed resting in trees. No such observation was recorded during the previous summer, but this may have been affected by the new and higher quality receiver, whose signal changed more clearly in response to whether the bat was staying still or flying. It remained unclear whether the bats found something to eat from the trees, whether they went to the tree to feed on larger-sized prey or whether they were simply using them as a place to rest. De Jong (1994) observed in his study carried out in central Sweden that the bats often used trees as night-time resting places. The same tree served as a resting place each night; it was located less than one hundred metres from the roost. This may have been the bats' way of avoiding leading any predators close to the colony. This behaviour may also have a social purpose (de Jong 1994). Generally, a bat was alone in a tree, but sometimes it might also move out of the way of another bat that approached the tree. The longest period of time that a bat rested in a tree was nearly one hour, but usually the bats only rested there for a few minutes at a time. The regularity of the signal indicated that the bats were resting in trees or other suitable places also when they were feeding along the shorelines of the strait. It was not, however, always possible to confirm this.

In Kaarina, the bats were observed occupying short-term feeding territories, which they defended from any conspecific intruders. When two northern bats encountered one another, a chase nearly always ensued; the social calls were heard. Sometimes the bat that had occupied the territory was able to retain it, but every so often the intruder succeeded in evicting the founder of the territory. Several bats could also sometimes forage in the same area if there were high concentrations of insects available. In his articles, Rydell described this type of behaviour by northern bats, defending their feeding territories, as well as other observed foraging behaviour (Rydell 1986).

The objective of the study was to find the bats' summer foraging areas, their late summer hunting and swarming areas as well as their hibernation sites. Unfortunately, this ambitious objective was not met. The capturing attempt on 28 July 2007 at Tuulikinkatu was unsuccessful, since the majority of the bats had moved elsewhere, and catching the few remaining individuals was not successful. The house on Tuulikinkatu road was a challenging place to carry out a capture, because the bats were able to emerge through various holes at both ends of the roof, and there was no clear primary route. All three of the female bats that were the last to be radio-tracked also managed to remove their transmitters in the attic of the house.

The effect of temperature on hunting activities

Although the temperature and humidity were also measured together with radio-tracking, this report includes the weather information provided primarily by the weather station of the Finnish Meteorological Institute. The measured parameters included temperature, relative humidity, wind direction, and wind speed in metres per second.

The daytime temperature during the first tracking period, 4–8 June 2007, was at least 21 degrees Celsius and exceeded 25 degrees during three of the days. On three nights, the night-time temperature dropped below ten degrees, but was never below six degrees.

The second tracking period, 11–19 June 2007, was cooler. During the days, the temperature remained between 10 and 20 degrees. The night-time temperature dropped below 10 degrees on many nights, and on two nights the figure was below six degrees. This affected the bats' hunting activities. On those colder nights only few bats emerged, and they often stayed out for only a short time.

The third tracking period, 17–23 July 2007 was quite cool and variable. Rain showers occurred almost daily. The weather did not seem to significantly affect the bats' activities. On the other hand, some of the bats had, at that time, already moved away from the bat house, which affected the surveillance of their movements. This radio-tracking period was also shorter than those of the early summer.

The video image shows that there were more bats visible if the outdoor temperature was high. This indicates that in cooler weather conditions, when the attic is cooler, the bats seek out hideouts between the battens under the tin roof, where even the slightest amount of sunshine provides warmth. When the temperature outside of the building rose, it became too hot under the roof, and the bats moved down the side of the chimney, where the camera captured their images.

4.2 THE SIGNIFICANCE OF THE BAT HOUSE TO THE NORTHERN BAT COLONY

One of the aims of this study was to find out whether there are alternative roosts suitable for a maternity colony of northern bats in the vicinity of the bat house. Of the radio-tracked bats, only Beata used a roost other than the bat house, but only for one day during the tracking period. She left the house due to the disturbance caused by the attachment of the transmitter, but returned in the early morning hours of the next day. In 2006, she did not dare to return to the house until the sixth day after the capture. In both instances, the refuge was the same; a single-family home located on Kuusisto island, approximately four kilometres east from the bat house. This type of behaviour is quite typical at the beginning of the summer, the time when the colony has not yet settled and the bats have not yet given birth to their young. Beata's temporary absence due to the researcher's disturbance was to be expected, since the same reaction of the northern bats was also observed, for example, in Sweden (Rydell 1989c). Later in the summer, the bats were not significantly disturbed by the capturing and handling.

By the third capture, the young were already able to fly. Soon after, the colony left the bat house. The point in time had been the same in earlier summers. Some of the bats may have had already departed from the house prior to the final capture. Liisi was found the day following the capture, on 17 July 2007, at Tuulikinkatu 2. The terraced house, the roof structures of which had apparently been occupied as a roost by the majority of the bat colony upon leaving the bat house, was located 490 metres from the bat house. Naima and Maija were still at the bat house at that time, but on the same night, Naima also visited the Tuulikinkatu roost before returning once again to the bat house, along with Maija. In the early morning hours of the next night, 18 July, Naima moved to the Tuulikinkatu roost. On 19 July, Maija also showed up at Tuulikinkatu, and thus all three had made the move to the new roost.

The movement of the colony appears to have taken place in phases, and it is possible that the development of the young of the radio-tracked females were at slightly different stages, thereby affecting the timing of such a move. It is probable that the majority of the bat house colony moved to Tuulikinkatu once they had weaned their young, since there was a great deal of activity recorded at Tuulikinkatu around the same time that the yard of the bat house seemed to quiet down. The splitting up of the colony once the juveniles are able to fly is common among many species of bats. Reasons for this behaviour can be for instance efforts to avoid predators, disturbances, avoidance of an increased number of external parasites, changes in the microclimate, and the desire to move closer to better foraging areas (Lewis 1995). In the case of the Kaarina colony, none of these reasons can alone explain the split of the colony.

This study further confirmed the understanding about the bat house as the primary roost for the colony from the turn of May–June until the end of July. This is significant in terms of reproductive success since the females stay in the roost during pregnancy and lactation. The pups grow up in the bat house and return there after their first flights. In early summer, before the colony is formed, the bats may temporarily change their roost, as was the case in Kaarina, but in both 2006 and 2007 the bats that had been spending time elsewhere also came back to the bat house to give birth to their pups. Once the young bats were able to fly, the colony abandoned the bat house and moved to a new roost. Some of the bats may also have moved elsewhere, as happened in 2006. In that study, one bat, Freija, moved from the house to the roof structures of a block of flats on the other side of the hill. This building was located 210 metres from the bat house. Freija also visited Tuulikinkatu, so the place was familiar to her. Presumably same individuals use the same late summer roosts every year.

The colony of the bat house in Kaarina is the largest known maternity colony of the northern bat in the area. No other bat species were observed in the area considered to be the centre of Kaarina, with the exception of a young whiskered bat (*Myotis mystacinus*) male. The bat was found hanging on the wall of Kaarina Health Centre on 6 August 2007. Individual northern bats were observed foraging in small wooded hills in the city centre. As the radio-tracking study went ahead, it started to seem that most of the observed bats of the city area originated from the bat house colony. If the bat house was to be demolished, the northern bat may lose its reproducing population from the centre of Kaarina, at least temporarily.

The microclimate of the attic might have been altered in an unfavourable direction, because the house has been unheated since 2007. The shadowing of the new buildings may, in time, further weaken the conditions of the abandoned house in terms of its suitability for the bats. However in 2008, the usual number of bats arrived at the house and reproduced there normally, even though it had been without heat for six months.

4.3 A BAT BOX – A SUITABLE ROOST FOR THE NORTHERN BAT?

The third objective of the study was to clarify whether bat boxes are sufficient as roosts for northern bats. The bat boxes would be a simple solution to use as new roosts. Several bat boxes were hung in the yard of the bat house. Some of the boxes were made of wood, and others were a blend of sawdust, concrete and clay. It has been shown that northern bats accept wooden bat boxes which they can enter by crawling along a sheltered entrance (Gerell 1985). The wooden bat boxes hung in the yard of the house were specifically of this design. The northern bats in the bat house, however, were not observed using these boxes, or

any others, as roosts. The boxes from the yard also showed no evidence of having been visited by bats. On the other hand, bats have often been shown to accept boxes that have been in the trees and weather-beaten for several years.

In Norway, a test was conducted during 2005 and 2006, where northern bats were provided with bigger boxes that were 60 centimetres high and 40 centimetres wide. As a result of the test, researchers were able to move a colony of about 40 northern bat females from inside a building to the box hung on the outer wall of a building. Only ten females remained inside the house. No forceful methods were used to move the bats, and they still had the opportunity to return to the inside of the building. This proves that bats consider the boxes to be a better roost than the attic of a building (Michaelsen et al. 2006). A box designed in accordance with the Norwegian model was hung on Kaarina's water tower during the autumn 2007, and the hope was that it would attract the northern bats. There are no observations whether or not the box has been accepted by bats.

4.4 MEANS OF REDUCING THE THREAT TO BATS POSED BY CONSTRUCTION

The fourth objective of this study was to consider how to reduce the threats to bats caused by construction. In many European countries, such as Great Britain, bats are generally taken into consideration during the planning phase for land use. The local planning authorities can turn down applications if it is determined that the plans may pose a threat to protected species, or if the assessment of the environmental hazards, in relation to the protected species, is considered insufficient. In the planning stage, different mitigating measures can be settled upon in order to ensure that the threat to the animals or other organisms is as minimal as possible. These measures are often a condition that must be met in order for a building application to be approved. The applicant must prove that there were no other viable alternatives, and that the measure will not affect the favourable conservation status of the species.

In 2004, Bat mitigation guidelines were published in Great Britain. They were intended to provide builders with the means to minimise the threats to bats caused by demolition and new building work (Mitchell-Jones 2004). In some cases, the implementation of this work can take time. It is important to ensure that the work is carried out at the right time regarding the critical annual cycle of the bats and that the roosts and hibernation places are retained. If this is not possible, then new roosts must be provided for the bats. These types of artificial roosts may be bat boxes hung in trees, buildings built exclusively for the bats, or roosts imbedded in the walls or roof structures of new buildings. The success of the work requires that bat experts oversee the progress of the work related to the bats and monitor the adaptability of the bats to the changes during the construction phase as well as after the building work is completed.

In Kaarina, efforts to minimise the threats to the bat colony could include providing room for roosts in the new buildings and alternative roosts in suitable areas as well as properly scheduling the dates of the construction work. Ideally when constructing blocks of flats around roosts, the work that causes the most noise and trembling should be carried out during a time other than the critical reproduction period, from May to August, with a break at least over June and July.

If the bat house were to be demolished, it would be possible to build new, heated spaces for the bats in the blocks of flats or outbuildings that are to be built next to the bat house. Currently, there is insufficient evidence to show how willingly northern bats will take to alternative roosts, nor it is known with any degree of certainty what type of spaces should be created in order to appeal to the species. There are a variety of methods that could also be tested in Kaarina to attract the bats. Since many of the bats of the bat house have been banded, it would be possible to identify them if they moved into the new roosts. It is advisable for the roost spaces to be built so that the researchers have access to them and can, for example, install cameras there for surveillance purposes. This would also facilitate the care and cleaning of the roosts, while ensuring that they are isolated from the residential flats.

If the roosts created in connection with new buildings are not accepted by the bats, they could be offered several alternative roosts in properties owned by the City of Kaarina. Bats are, however, particularly cautious in new environments. For this reason, it may take a long time before they accept the new areas as roosts.

The life of the northern bat colony at the bat house in Kaarina has been tracked and documented for several years. The radio-tracking project started in the summer of 2006 was the first of its kind, and helped to establish new information about the northern bat's foraging behaviour and daily activity in Finland. The northern bat colony at the bat house should continue to be monitored, particularly now when there are blocks of flats being built nearby. Bats emerging from the house should be counted regularly during the summer and the camera surveillance of the colony must be continued.

With the help of the Kaarina bat house case, it would be possible to obtain information which can also be utilised elsewhere, when assessing the effects of land-use solutions on bats. This information would enable us to create guidelines for similar cases. Video and audio observation with bat detectors should also be continued alongside the implementation of the construction work. The bats also need to be banded and recaptured over the coming summers in order to determine whether the same individuals remain in the house despite the disturbance of the construction in the vicinity.

Today, the new blocks of flats have stood in the vicinity of the bat house already for several years. The house has remained unheated and abandoned. In the June 2013, 14 adult northern bats were counted and also their young had been seen. In the year before, the number of the adult females was 13 and before that 11. The number of bats has declined from the years of the radio-tracking studies, but the reason for that is unclear. In addition to the changes in the microclimate of the house, the harsh weather conditions of last four winters can also be the reason for lower numbers.

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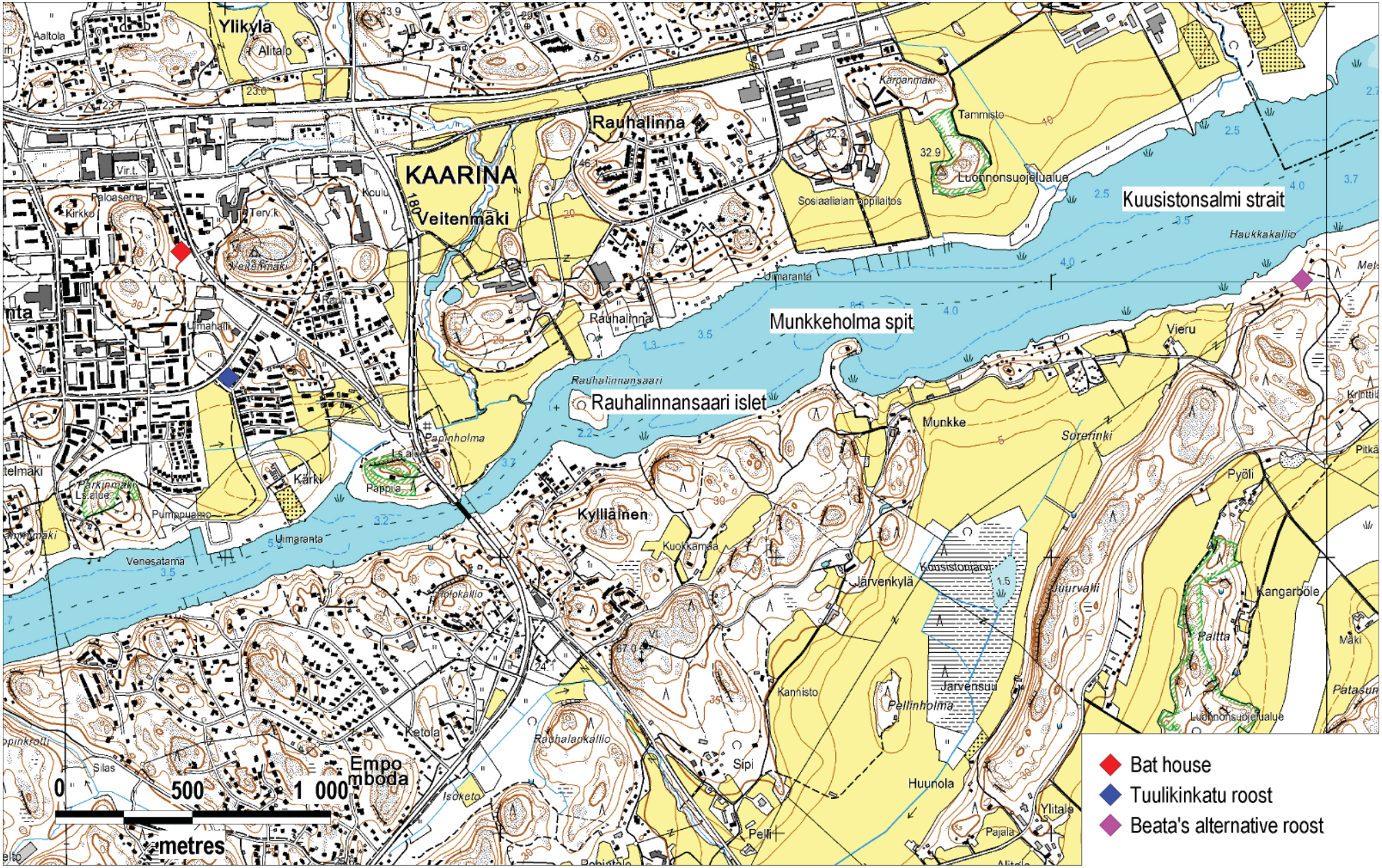
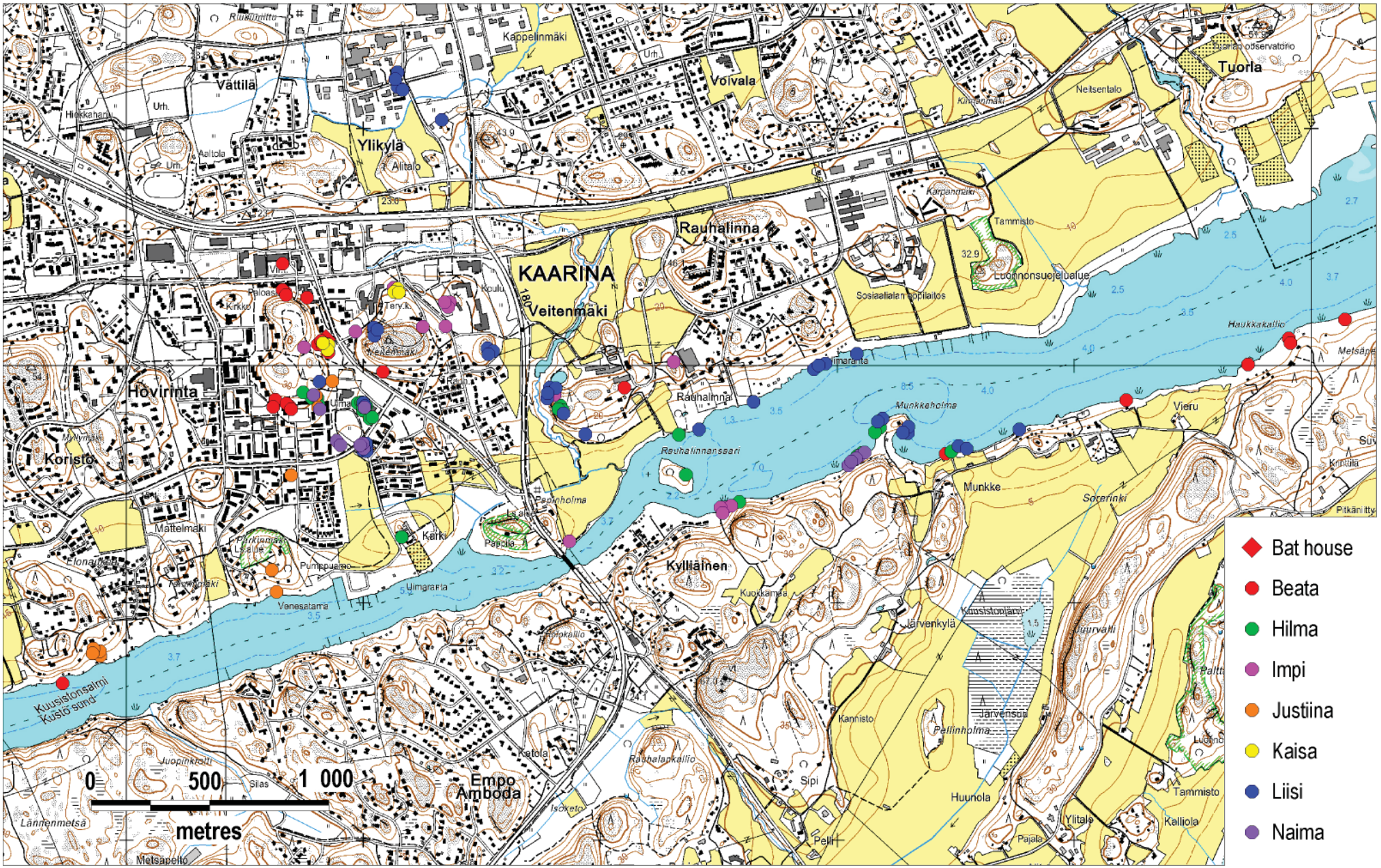
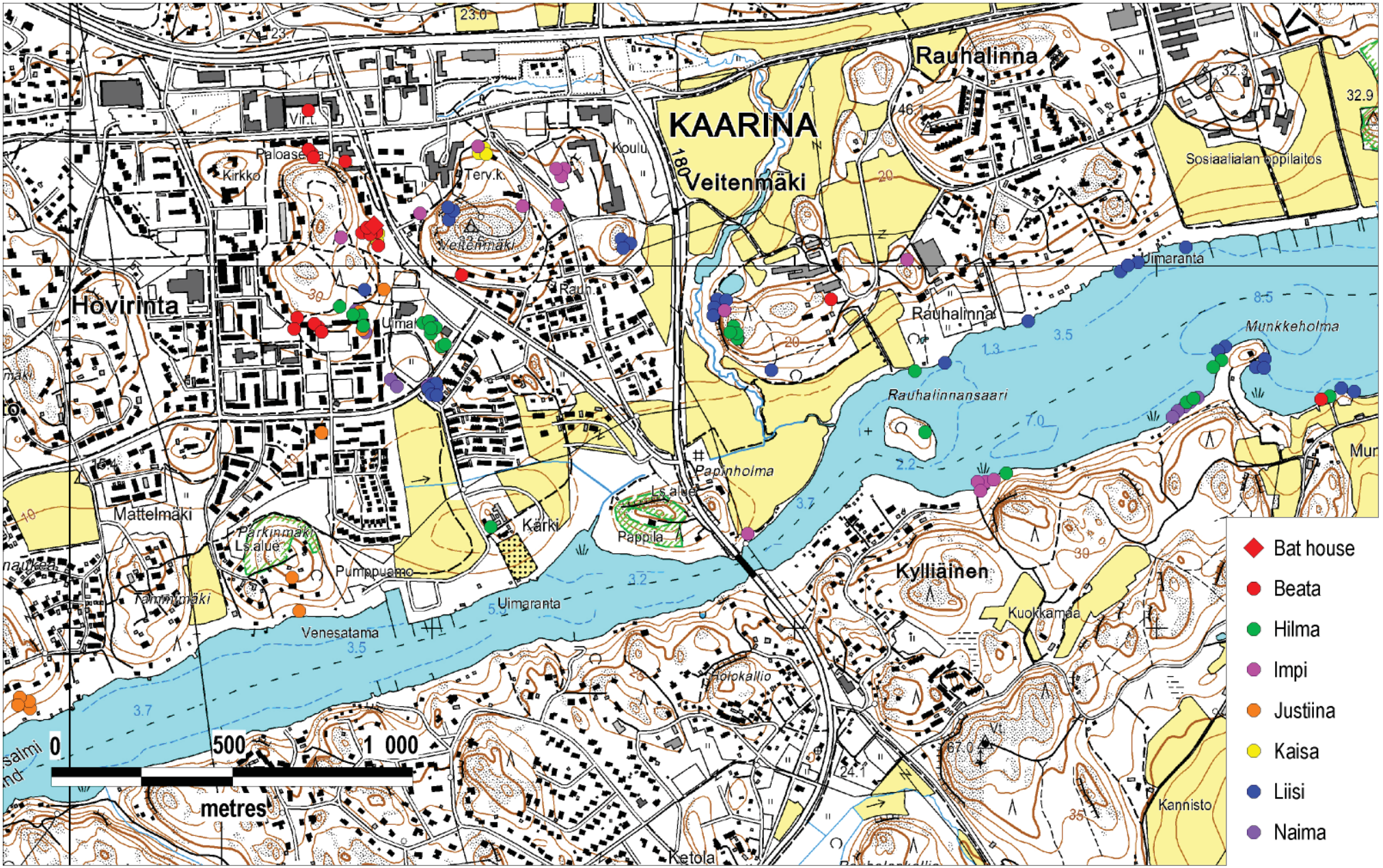


MAP 1. *The known roosts used by the northern bats of the bat house.*



MAP 2. *The locations of all radio-tracked bats during the summer of 2007.*



MAP 3. *The locations of all radio-tracked bats during the summer of 2007.*