Radio-tracking bats: a short review with examples of a study in Italy

Fabio Bontadina[1], Dino Scaravelli[2], Sandra Gloor[1], Therese Hotz[1] & Andres Beck[1]

[1] SWILD - Urban ecology and wildlife research,
Wuhrstrasse 12, CH-8003 Zürich, Switzerland.
[2] Riserva Naturale Orientata di Onferno, Comune di Gemmano, piazza Roma 1, 47855 Gemmano, Italy.

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Abstract

Chances and limits of radio-telemetry of European bat species are presented based on a telemetry study about Rhinolophus ferrumequinum in Italy. As prerequisites for the use of radio-tracking, study objectives and research design, weight and attachment of transmitter and radio-tracking equipment are discussed. Literature and examples from the field study are given concerning activity, selection of roosts, foraging areas, habitat use and behavioural observations. A list of references and some web resources should help to find further information.

Introduction

Bats forage in the dark and often move very fast. Therefore we need a special technique to study their nightly activity. Radio-tagging, the marking of bats with a small radio transmitter, is one of the unique tools to study moving and activity patterns of individual bats (Wilkinson & Bradbury 1988). This method provides information of the bats' behavioural ecology and it contributes to the knowledge needed for the conservation of endangered bat species.

The aim of this paper is to present chances and limits of radio-telemetry of European bat species based on studies recently carried out and by this means to provide some of the most important references on the topic. In addition we try to give some useful recommendations for beginners.
To illustrate the application of telemetry, we present some results of a study about Rhinolophus ferrumequinum in the Romagna region (paragraphs in italics), which is one of the first radio-tracking studies on a bat species in Italy.

The greater horseshoe bat

Originally the greater horseshoe bat Rhinolophus ferrumequinum (Schreber, 1774) was a Mediterranean species, but it was able to expand its distribution area to the north because it had the ability of using human buildings for reproduction. Only 50 years ago this species was widely spread and known to be common in Central Europe. Since then the populations of the greater horseshoe bat have experienced a dramatic decline. Today it is thought to be one of the most endangered bat species in Central Europe (Stebbings 1988). Pesticides, the changes of the landscape, and the loss of roosts are supposed to be the most important reasons for their decline (Ransome 1990, Stebbings & Arnold 1989, Roer 1983-84). Habitat use of Rhinolophus ferrumequinum has been studied in different landscapes of Europe (Stebbings 1982, Jones & Morton 1992, Duvergé & Jones 1995, Geiger 1996, Pir 1994, Bontadina et al. 1995, 1997).

We chose a colony in the Mediterranean region of Romagna in northern Italy to study habitat use of this species in its original distribution area. In this area the greater horseshoe bat is the most often observed bat species in caves apart from Myotis myotis/blythii and Miniopterus schreibersi (Gellini et al. 1992, Scaravelli unpubl.).

Study area and methods

The Romagna region is located in northern Italy and it has its bio-geographical boundaries along the northern Apennine ridge, the Adriatic sea and the beds of the rivers Santerno and Reno, covering an area of about 1000 km². Half of it is a plain with mainly intensively cultivated orchards, the other part belongs to the Apennin mountains. More than 40 sites of the greater horseshoe bat are known in this area, most of them are winter roosts in caves. Usually only a few and never more than some dozens of individuals are found in the roosts (Bassi & Fabbri 1984, Gellini et al. 1992, Scaravelli & Bassi 1993, Scaravelli unpubl.).

The starting point of our investigation was a nursery roost, situated on the first floor of an old unoccupied villa and a roost in a nearby artificial cave system of an old fortification. These roosts are situated in the village of Terra del Sole (UTM-GRID reference T32 QP39), a typical Renaissance place, situated in a hilly area (50 to 300m a.s.l) near the Apennin Mountains. The colony has 40 adult individuals and has been known for several years.
We mist-netted greater horseshoe bats on flightpaths outside of the roost of Terra del Sole and radio-tracked 9 females and one male in May 1994 during their first foraging bout.

Prerequisites for the use of radio-tracking

Radio-tracking opens a lot of possibilities, but also has its limitations. We would like to address some points which have to be considered when radio-tracking is being used. These points are not only important for the animal safety but also for the quality of your data.

1. Transmitter weight

The weight of the transmitter is one important limitation when working with small flying animals such as bats. A rough rule says that a transmitter should not be heavier than 5% of the bat's body weight (Aldridge & Brigham 1988, Caccamise & Hedin 1985). In exceptional circumstances and for short time studies transmitters of up to 10% of body mass were used before, but a surplus weight of this range influences the flight performance of the bat, and reduces its manoeuvrability (Aldridge 1985-86). Hickey & Brian (1992) showed that the studied bat species reduced catching success as a consequence of the transmitter load.

Before starting to put the transmitters on the bats, you have to be sure that the size, the shape and the weight of the transmitter influences the behaviour of the animal as little as possible. And of course the cumulative mass of transmitter, glue and wing bands has to be considered.

In Romagna we caught 23 greater horseshoe bats. Their weight differed between 16 and 25 g (mean 18.8 +- 2.6 g). The heaviest individuals were clearly pregnant females, so we didn't load another extra weight on these bats. We chose 10 of the other bats with an average weight of 20.0 g. The used transmitters (Holohil model BD-2B) with position sensing, which were specially designed for this species (long and narrow) have a total weight of 1,1 g inclusive glue for attachment. Therefore the extra weight of the transmitters ranged between 4.4 and 6.1% of the studied animals' body weight.

2. Transmitter attachment

You have to decide how the transmitter should be fixed to the animal. It can be glued to the back or fixed with a collar. On different species it has to be fixed differently.

If you decide to glue the transmitter to the back of the bat, the use of a medical glue or an eyelash glue is recommended. Unlike cyanoacrylat instant-glue they stay elastic and are not poisonous. Usually the transmitter is scraped off by the bat after some days.

Collars can be made of different materials (plastic or silicon) and may be delivered by the provider if ordered. When using collars, they need to have a point of fracture where they wear out and fall off after a certain time. This problem may be solved by a small peace of strong paper placed in-between the collar (see figure in Fuhrman & Seitz 1992).

In our study we fixed the transmitters with SkinBond to the back (for an instruction see the web-page from Holohil, appendix I). Former tests with a caged animal have shown that the use of collars on greater horse-shoe bats is not possible because of their special hunting technique (perch hunting, see chapter "5. behavioural studies").
The transmitters dropped off after 2 to 11 days (median 4.5 days, n=10). In comparison to our experiences of studies in Central Europe this is short, probably induced by the higher roost temperature.

3. Radio-tracking equipment

There are a lot of different providers who sell radio tracking material and who are specialised on different types of material. To find out which provider sells the best material for the species you plan to work with, it is worth talking with people who already work with the same or similar species. Profit of other people's experience! In appendix I we list some www addresses, where you can get helpful information.

4. Objectives and study design

Radio-tracking opens a wide field of topics and questions you can work on (Amlaner & Macdonald 1980, Wilkinson & Bradbury 1988, Priede & Swift 1992)). However, for every question you want to answer, you have to collect different data. So it is necessary to plan your study as well as possible, to ask yourself what exactly you want to know and which data you need to answer your question, or to test your hypothesis. How to collect data is defined by the bat species. So it is possible for more sed-entary species to locate them by one person with the "homing-in" method (used e.g. by Arlettaz 1996). Other species, which are foraging

by aerial hawking in big areas have to be located by crosstriangulation (e.g. Bontadina et al. 1995), for general information about the data sampling methods see White & Garrott (1990). It is important to plan all this before you start working in the field.

You always study individuals when radio-tracking and you need to have in mind that you can get data only from a few animals. On the other hand, very often you can collect a large amount of information from the few individuals tracked. This has statistical implications: if you like to draw conclusions about a population of bats and not only to describe the behaviour of the studied individuals, you need to study at least 6 to 8 animals of the same age, class or sex, and it would be even better to track ten or more animals just to be on the safe side (basic conditions for application of statistical tests, see e.g. Sokal 1981). This means a lot of work has to be done to get enough data. In fact, radio-tracking is a very time consuming method. Moreover it is a high-tech method, and you need quite expensive equipment such as transmitters, receivers and antennas.

After you have collected the data, the big job to analyse them will start. Today there is a great amount of techniques, software and statistical methods available for the sampling and the analysis of radio-tracking data. It would exceed the possibilities of this short review to present all of it. So we only refer to some extending literature (Wilkinson & Bradbury 1988, Harris et al. 1990, White & Garrott 1990, Worton 1989, Aebischer et al. 1993, for software see the references about web pages in appendix I).

Radio-tracking in behavioural ecology studies of bats

1. activity

In difference to e.g. emergency counts at a roost, where you get an impression of the activity pattern of the whole colony, with radio-tracking you get the activity pattern of an individual bat. You can find out when the tracked bat leaves its roost, when it hunts or moves to another place, when and how long it rests or sleeps and when it returns

to its roost. Most of the time it is possible to tell whether a tracked bat is moving or not because the transmitter signal changes its loudness as soon as the bat moves.

Determination of the activity by radio-tracking was used in Nyctalus noctula by Kronwitter (1988), in Rhinolophus ferrumequinum by Jones & Morton (1992), in Plecotus auritus by Fuhrmann & Seitz (1992), in Eptesicus nilsonii by De Jong (1994). A study on activity with implications for conservation are described in Jones et al. (1995).

We observed the male greater horseshoe bat M1 during the whole night of the 13th May 1994. It showed two phases of activity. The first foraging bout was from 20:45 until 21:50 (duration 55min), then the male returned for night roosting and started again at 3:57 until 5:15 for 78 minutes.

Out of 7 animals we could observe the duration of the first foraging bout 9 times. The time of leaving the roost is very similar, but the length of the first bout has a great variance (median duration 98 minutes, range between 42 and 305 minutes, n=9, Fig. 1). The data seems to show an increase of the foraging duration in May, maybe because the time of parturition approaches.

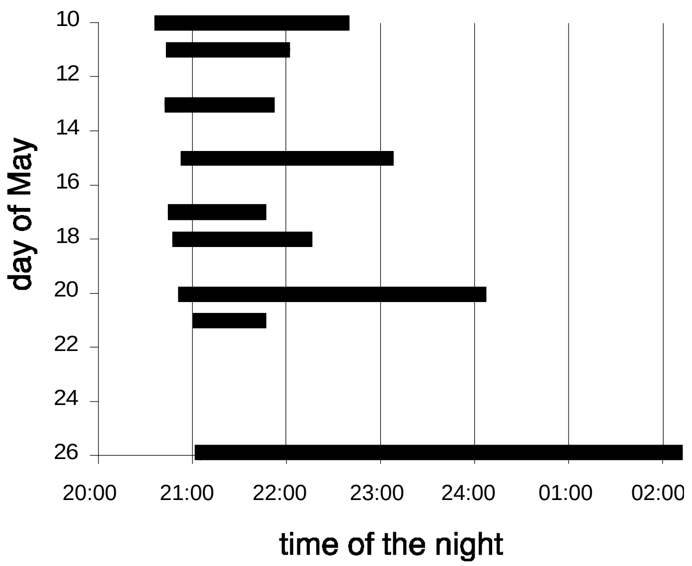

Fig. 1: Foraging activity of 9 Greater horseshoe bats in Romagna during their first foraging bout.

2. Selection of roosts

Usually roosts of bats are found by checking a certain type of building or cave. This method gives a biased picture of bat roosts, because you only look in certain places, where you think it could be possible to find bats and you can only find the most obvious roosts.

The only unbiased way to find roosts is to radio-track bats and to find every roost during a longer period. To be sure to have an unbiased data set of roosts, you really need to have every roost for a certain time and not only the ones that can be found easily; this sometimes is a very time consuming challenge. Knowledge about the roost of a colony, especially of nursery colonies, can be crucial to implementing conservation measures.

Until now roost selection in European bat species has been investigated systematically by radio-tracking only in a few studies. Kronwitter (1988) and Bontadina & Gloor (1994) studied tree roost use in Nyctalus noctula, Fuhrmann & Seitz (1992) in Plecotus auritus. Geiger (1996) and Beck & Schelbert (in press) used radio-tracking to locate the nursery colonies of relict populations of Rhinolophus ferrumequinum.

In Romagna we controlled the use of roosts of the 10 studied animals during 47 animal-days. They only used a few different roosts.

During the 47 animal-days 5 dayroosts (3 in houses, one in an underground place and one in a unknown place) and 3 exclusive nightroosts (two in churches, one in an unoccupied house) were used. Two of the dayroosts were found to be used as nightroosts as well. Two animals disappeared and we could not find them any more, neither at day nor at night, although we searched an area of more than 500 km². Two animals changed to other dayroosts, 1 km and 11 km away. One of them proved to be a new nursery roost. Three months later the marked bat was refound in that place in a group of 65 adult and juvenile greater horseshoe bats.

bat code	observed days	# of day-roosts	# of night-roosts	cause for end of observation
M1	11	2	2	transmitter loss
F7	10	2	1	transmitter loss
F3	4	1	?	transmitter loss
F5	6	2	2	transmitter loss
F17	3	2	?	transmitter loss
F11	1	1	1	bat disappeared
F13	4	2	?	transmitter loss
F23	3	1	?	transmitter loss
F27	3	1	?	transmitter loss
F15	2	1	?	bat disappeared
total 10 animals	total 47 day-roosts	total 5 different day-roosts	total 3 exklusiv night-roosts	

Tab. 1: Use of day roost by 10 greater horseshoe bats in Romagna. The bats only used one to three different roosts in the study period of May.

3. Flight paths and foraging areas

The technique how to take fixes of flying bats depends on the species specific behaviour. If the animal forages at patches for a longer time, it is possible to reveal the animal's place by taking two or more successive bearings from different vantage points ("homing in"). If an animal moves fast and for longer distances, two mobile people or some fixed aerial-towers are needed to track synchronically. Cross-triangulation means that the location of the animal is where the two ore more bearings cross (for the methods see White & Garrott (1990), Wilkinson & Bradbury (1988)).

Commuting time of bats is usually short and they then fly very fast, therefore it is nearly impossible to estimate accurately flight paths with radio-tracking. Often it is necessary to wait near an expected flightpath and to check with the receiver whether the bat is passing (e.g. Rieger et al. 1990). Some bat species commute every night up to 26 km to their

foraging areas (Myotis myotis, Audet (1990), Arlettaz (1996), Güttinger 1997).
On the other hand there are bat species, that stay in small foraging areas nearby after leaving their roost (e.g. De Jong (1994), Flückiger & Beck (1995), Fuhrmann & Seitz (1992)), whereas others forage on the wing in much greater areas (Kronwitter (1988), Sierro & Arlettaz (1997)).
Examples of the spatial use of bats revealed by radio-tracking you can find in every field-study quoted in the references. Duvergé & Jones (1995) and Bontadina et al. (1997), as for example, derive from these field studies implication in the conservation of foraging areas.

We worked with the method of cross-triangulation because of the rapid movement of our studied greater horseshoe bats in Romagna. The area was quite selectively used by the bats. After leaving the roost they used flightpaths in different directions. Often the river was used as a flight path. All the animals we observed foraging on the plain passed along the river. They did not use small areas for foraging, but often changed continuously to a larger area. Only while perch-hunting from twigs (see „5. Behavioural studies“), they stayed at the same place for a longer time.
Although they sometimes crossed the nearby hills, they usually stayed in the valley of the day-roost for most of the observed nights. The maximum distance from the day-roost for foraging was 5.5 km, while most of the time they stayed at a distance of 1500 m to 4000 m apart from the day roost. This gives an implication in the protection of foraging areas. The most important area for protection lies within about 4 km around a colony.
There was no correlation between the observed utilisation density and the distance to the roost. This means that the bat foraged with the same frequency at any possible distance apart from the roost.

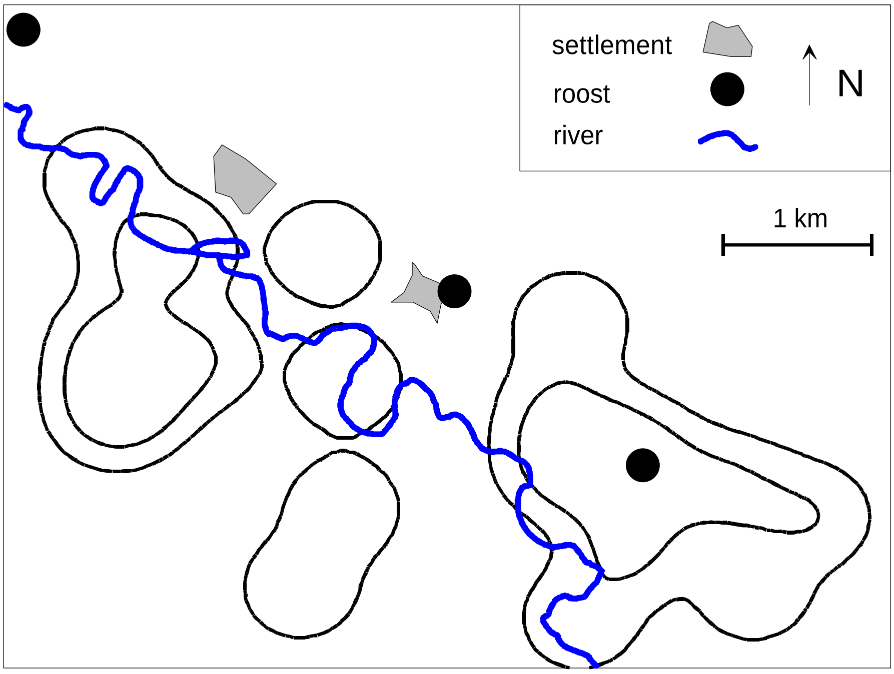

Fig. 2: Foraging area of male M1. The lines show the 90% and 50% kernel density estimation contour lines (computed from n=26 locations). They contain 90% and 50% of the estimated foraging areas, respectively.

4. Habitat use

The determination of habitat types is a key feature to describe association with vegetation or structures and to test hypotheses about niche separation between species. Data collection of habitat use with radio-tracking is normally based on the assumption that the duration of association is correlated with the relative importance of that habitat type (White & Garrott 1990). Habitat analyses give argument and priorities for conservation and land use management recommendations. All of the cited references to field studies about European bat species give information about habitat use.

The studied greater horseshoe bats foraged in different landscapes surrounding the day roosts. Their foraging areas were not restricted to the valley-ground, but they hardly crossed the hills and sometimes foraged in *bushes at higher altitude. All areas, where the bats could be observed for a longer time, were near the rivers at the ground of the valley. The most important foraging areas lied within 50m to the water, although we did not observe them foraging over the open water.*

The vegetation in the plain along the rivers, bushes and small trees, seemed to be suitable foraging areas. In the plain one animal also used intensively cultivated orchards for perch hunting. We could never observe greater horseshoe bats foraging in open areas.

5. Behavioural studies

Different methods like nightvision devices, light tags, infrared video equipment are used to study bat behaviour in the roost or in their foraging habitat. An overview is given in Barclay & Bell (1988). Marking the transmitter with a reflecting tape, makes it is easy to find the radio-tagged animal in a group or while it forages by using a torch or an infrared lamp.

Audet (1990), Arlettaz (1996) and Güttinger (1997) describe foraging behaviour in Myotis myotis and M. blythii, Bontadina et al. (1997), Geiger (1996) in Rhinolophus ferrumequinum. Catto et al. (1996) and Robinson & Stebbings (1997) give information for Eptesicus serotinus, Kronwitter (1988) in Nyctalus noctula, Rieger et al. (1990, 1992) in Myotis daubentonii, Sierro & Arlettaz (1997) in Barbastella barbastellus.

We could observe two foraging strategies of the radio-tracked greater horseshoe bats. They foraged in flight (aerial hawking) and by perch hunting. When perch hunting, the greater horseshoe bat hangs on a twig of a tree or a shrub, between 0.5 and 6m above ground (n=5 perches found) and waits for insects that fly by. The bat constantly turns around its body to both sides. If an insect passes by, the bat leaves its perch for a few seconds, tries to catch the insect and returns to the perch to eat the prey or to continue to turn around and to look for prey. Most of the perch hunting time, the bat is hanging on the twig. The maximum perch hunting period we observed lasted 3 h 10 min, the maximum time we observed it hunting at the same perch was 52 min.

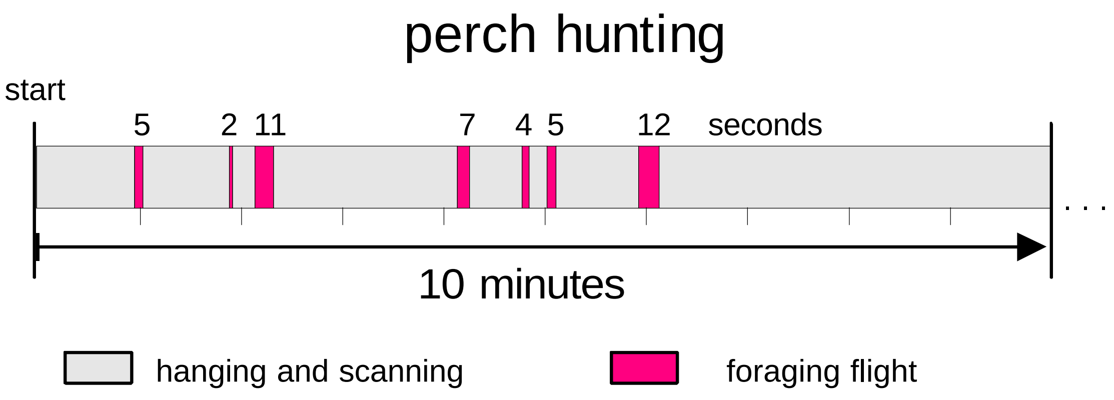

Fig. 3: A part of one perch hunting sequence of female F27 on 26th May 1994. Starting at 23:38, the whole sequence ended at 0:01, because of an interference with another greater horseshoe bat.

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Appendix I

Some useful www addresses:

(an online version of these links you find on www.swild.ch/telemetry)

Wildlife telemetry and software

- **Wildlife Ecology Software Server from Illinois Natural History Survey: http://detritus.inhs.uiuc.edu/www**
- **References for data processing and analysis software: http://www.uni-sb.de/philfak/fb6/fr66/tpw/telem/dataproc.htm**

Radio-tracking equipment

- **Directory of biotelemetry equipment manufacturers: http://www.biotelem.org/manufact.htm**
- **BioTrack: http://www.biotrack.co.uk**
- **Holohil transmitters: http://www.holohil.com instruction for transmitter attachment: http://www.holohil.com/bd2att.htm**
- **Titley Electronics http://www.nor.com.au/business/titley/index.html**

Mailing lists

- **Biotelemetry mailing list: http://www.bgu.ac.il/life/bouskila/telemetry.html**
- **Batline. Discussion group on bat research and education. Send an email to: esquire@basicallybats.org with body of the message:** *subscribe batline yourfirstname yourlastname*