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INSIDE THIS ISSUE:

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Tracking the social life of bats

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How do juvenile bats learn where to find food and roosts once they learn to fly?

This basic question puzzles researchers every year. In spring, female bats return from hibernacula to their birth sites and gather in so-called maternity colonies where they give birth and rear their young together. The result is that multiple generations of bats share a day roost and might potentially provide social information to that year's offspring. This information would help these offspring find the resources they need to survive. We know from experiments with adult bats that they are attracted when pre-recorded bat calls are played from roosts. This provides evidence that social information seems to play some role in localising roosts that are occupied by conspecifics. When it comes to finding food, there is plenty of evidence among insectivorous species that foraging bats eavesdrop on 'feeding buzzes', a series of echolocation calls that is emitted when a bat is closing in on an insect and indicates the presence of food to others. However, such mechanisms function over only rather short distances and may not be helpful for finding more distant resources. So what clues do fledging juveniles use during their very first independent exploratory bouts?

Noctule bats maternity inside bat house. © Linus_Günther

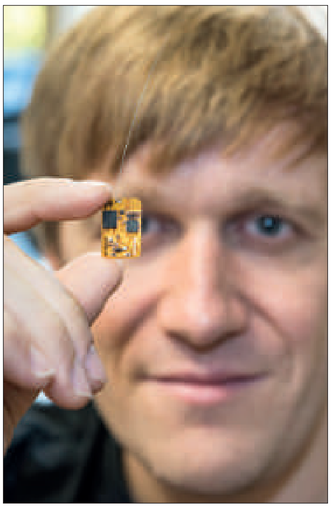
In a recent study, we evaluated the use of social information in fledging common noctule bats (*Nyctalus noctula*), a species that naturally roosts inside tree cavities but also uses artificial bat houses. The females return to the same area year after year and live in so-called fission-fusion societies. A fission-fusion society is where subgroups of a local population frequently split apart and re-unite while changing group composition and moving among a suite of regularly-visited roosting sites. Some roosts have been found to be occupied even across years, sometimes for more than a decade. As aerial insectivores, bats capture flying insects including mass-emerging ones such as mayflies. This means that the majority of food is available in certain places and at certain times. We therefore hypothesised that fledging offspring would follow their mother or other adults in the social group to unknown roosts or foraging sites.

It is surprising that this question has not been answered as it is fairly fundamental to our understanding of juvenile survival. The reason for this is that conventional tracking technology does not allow researchers to keep track of associations among individuals, in particular when they are flying. Radio telemetry, a technology that has been available since the 1960s and remains state-of-the-art in bat research, provides neither the temporal nor spatial resolution to detect bats flying together or close proximity among tagged individuals. More sophisticated GPS trackers could obtain this resolution, however, they weigh between three and four grams and using them on noctule bats, which weigh only 20 to 35 grams, would violate ethical guidelines in wildlife research. We therefore developed novel 'next-generation' tracking sensors in a collaborative and interdisciplinary approach alongside counterparts from the fields of electrical engineering and computer science. These proximity sensors only weigh between one and two grams, allowing them to be used on smaller animals than the GPS trackers. They function by scanning the environment every two seconds for other animal-borne sensors within a radius of up to 10 meters. Then, they download all collected data to base stations, which we deployed at roosting sites. The great advantages of these proximity sensors are that they are lightweight and data collection is fully automated, allowing us to track who is associated with whom around the clock and at a time resolution of seconds.

In 2016 and 2017, we captured 29 juveniles and 31 adult females from three social groups right at the point when the majority of the offspring had already fledged. We collected biopsies from the wing membrane for later molecular genetic analysis to determine kinship and identify mother-offspring pairs. We then used medical-grade glue to attach the proximity sensors to the dorsal fur of the bats. This ensures that the sensor drops off after around 10 to 15 days, avoiding a long-term impact on the animals. Once the bats had been released back to their roosts, the proximity sensors started communicating amongst each other and with the nearby base station underneath the roost. This provided us with two types of data: meetings with other tagged bats and presence signals at the base station that indicate presence or absence at a specific roost.

In the first step, we used the presence signals to identify two behaviours. First, we could see foraging bouts of juveniles. This occurred when a bat leaves a roost and returns to the same roost, typically after more than 30 minutes. Second, we could see when bats were switching roosts, that is to say if the bat leaves a roost and arrives at another roost within a few seconds or minutes. In accordance with our hypothesis, we expected juveniles that successfully switch roosts to be closely associated with at least one adult individual from the roost group when leaving the current roost and when arriving at the new roost. For finding rich foraging areas, we expected to see the same pattern when the offspring started a foraging bout and additional repeated associations while bats commute to a foraging ground.

We observed 16 events in which 12 different juveniles switched between two roosts while being associated with an adult bat from the group. On 12 occasions, the adult was the mother of the switching offspring. In some events, the juvenile bats used stopover sites and the mother returned to the original roost or stopover site and flew with the juvenile again, sometimes multiple times, until both found their way to the new roost. Such attempts at re-association suggest that the observed behaviour was not simply



Simon Ripperger with sensor node. © Carola Radke

Nyctalus noctula tagged adult. © Simon Ripperger

Field work checking roosts. © Benjamin_Günther

Field work tagging bats. © Mathias Burke

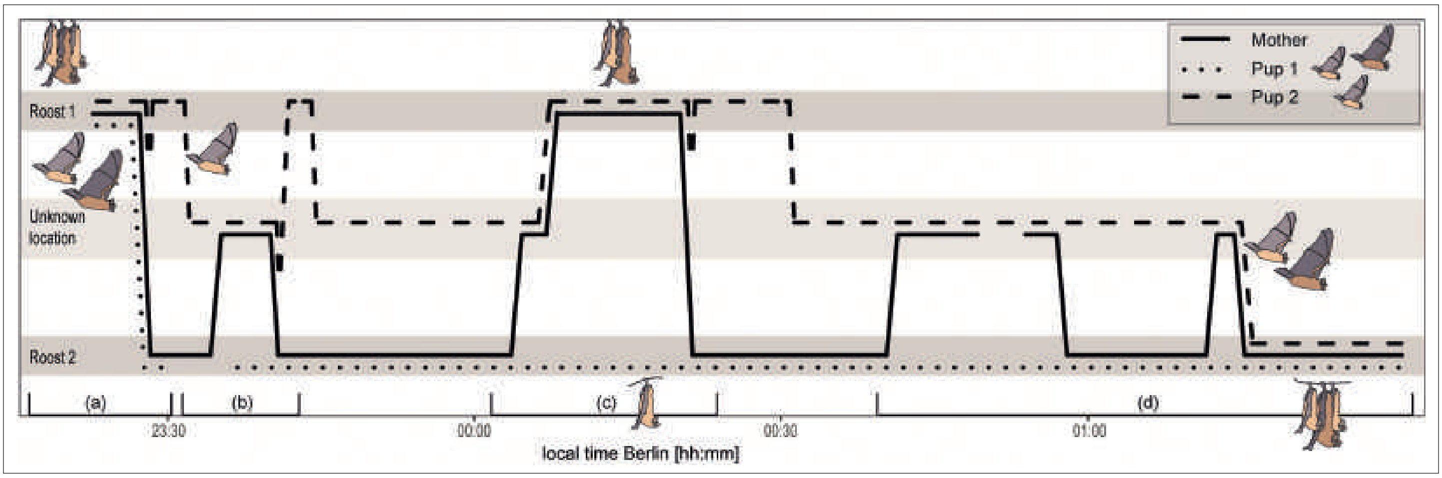
Field work catching bats. © Emrah Coraman

a juvenile following its mother but rather some form of guidance by the mother. **Fig.1** (below) illustrates such a case, where a mother that was attending to its twins flew to a new roost when they were separated. The mother then appeared to herd them while moving from one roost to another. When starting a foraging bout, however, juveniles were never associated with their mothers and co-roosting mothers started their bouts between four and 86 minutes before the young. In foraging situations, we detected 21 short meetings among juveniles and 11 other individuals, including one mother. In summary, 75% of associated bat pairs switching roosts were mother-pup pairs, but only 9% of dyads that met during foraging.

Our results suggest that juveniles rely on their mothers to become familiar with the colony's set of roosts but not when finding feeding grounds. Why is that? We believe that their broad diet, which includes various taxa of insects, enables young noctule bats to learn where and how to forage by trial and error. Furthermore, prey patches are ephemeral and any conspecific might provide social cues about prey locations, explaining the under-representation of mother-pup meetings during foraging activity. The quality of suitable roosting sites, however, might be much harder to assess for a naïve bat. Staying in touch with its mother is likely to be crucial for survival during the first few of weeks of a fledging bat's life since nursing by the mother extends post fledging and social contacts are beneficial for thermoregulation.

Our study was the first to use novel proximity sensors to shed light on the social life of bats, effectively illustrating how advances in technology can help us answer very basic questions in behavioural biology that have puzzled researchers for decades.

Noctule bat starts a bout. © Simon Ghanem



(Fig.1) Schematic representation of a mother and her twins switching roosts together, based on meeting data and presence signals. (a) A mother and her twins jointly leave roost 1 and the mother successfully moves to roost 2 with juvenile 1 (307 m distance). Juvenile 2 loses contact and flies back to roost 1. (b) Juvenile 2 moves from roost 1 to an unknown location where it is joined by its mother. Both initially fly together towards roost 2 but juvenile 2 flies back to roost 1 while the mother encounters juvenile 1 at roost 2. (c) The mother joins juvenile 2 at an unknown location and they jointly switch to roost 1. They jointly leave roost 1, but only the mother arrives at roost 2 starting and associates with juvenile 1; meanwhile, juvenile 2 flies back to roost 1. (d) The mother joins juvenile 2 at an unknown location. At around 00:50 the meeting is interrupted for several minutes before the mother commutes twice between its two juveniles. Finally, around 01:15 the mother and juvenile 2 successfully switch to roost 2. All three bats stay at roost 2 until shortly before 02:00.