An overview and evaluation of methodologies for locating the summer roosts of pond bats (*Myotis dasycneme*) in the Netherlands

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Abstract: During a long-term and intensive study in various parts of the Netherlands we employed five survey methods to find pond bat (*Myotis dasycneme*) roost sites: church loft inspections, telemetry, tracking back commuting routes, searching for swarming and involving the public through using questionnaires or requests for information about roosts in newspapers. In this paper we aim to help improve the effectiveness of survey methodology by presenting a description of the materials needed for each method, the optimal timing and duration and practical tips. Each of the methods employed provided different results in terms of the effectiveness, selectiveness and efficiency in finding roosts. To review the efficiency of a method, we calculated the number of days of preparation and research needed to find one new roost. On average church loft surveys took 43.5 days to find a new roost, telemetry 7 days; tracking back 7 days; and swarming 9.4 days. Each method has specific requirements; such as experience, specific material and licence. It is always wise to consider the feasibility of a method and the most appropriate method for ones' goal and the given moment in the bats' life cycle. This said, all kind of combinations of the methods described can be made.

Keywords: pond bats, roost sites, life cycle, searching for swarming, tracking back routes, church loft inspection, telemetry, questionnaires, surveys.

Introduction

The pond bat (*Myotis dasycneme)* has a primarily northern distribution, ranging from the Netherlands and Belgium as the most western part to the Yenisei River in Russia as the most eastern part (Limpens 2001b). Areas with high densities of maternity roosts are the Netherlands and the Baltic States, although high densities can also be found in other countries lying between. It is considered one of Europe's rarer and more threatened species and is protected in both Dutch national legislation and European law. However, lack of information on its ecological needs and its occurrence sometimes prevent this status being transformed into effective conservation measures. One of the main bottlenecks in the national and international protection of pond bat populations is the vulnerability of their summer roosts. The species has a high roost site fidelity and congregates in large numbers at roost sites. Owners of roosts are mostly oblivious of the presence of a *rare* bats species and can sometimes accidentally destroy the roost or imprison the animals, for example when they renovate their house or other property.

Previous national and regional survey projects have frequently discovered previously unknown roosts, even in areas where the species was not known to occur. Despite this an estimated 40% of the maternity roosts and 80% of the males roosts in the Netherlands, remain unknown. Appropriate timing of the survey period is essential for identifying undiscovered roosts. During seven years of intensive searching for roost sites in the

Table 1. Summary of the life cycle of pond bats. Male and female pond bats use several roosts during the year. The roost choice of females depends on their reproduction stages. The roost choice of males partially overlaps that of females. The main activity pattern throughout the year is also shown. Each phase has a beginning and ending (light grey shade) and a peak (dark grey). Males arrive earlier in the mating roosts, due to their territorial behaviour.

months	JAN.	FEB.	MAR.	APR.	MAY	JUN.	JUL.	AUG.	SEP.	OCT.	NOV.	DEC.
reproduction phase	sperm storage		Ovulation & fertilization	pregnancy		birth		growth of young		mating		sperm storage
type of roost	hibernacula			temporary roost		maternity roost			temporary roost		hibernacula	
type of roost	hibernacula				male roost		mating roost		hibernacula/mating roost			hibernacula
activity	hibernation		migration			in summer area		migration			hibernation	

Netherlands, we have used several methods, seeking to optimise the timing of the survey and the method employed. The choice of a survey method is also dependent on the expected bat density and group size in an area. Pond bats are not evenly distributed throughout the Netherlands: the provinces of Friesland, Northern Overijssel, Noord-Holland and Zuid-Holland are considered to accommodate large pond bat summer populations. These are the Dutch lowlands, consisting of peat, marshland, meadows, lakes and a dense network of waterways. Females seem to predominate in these areas. Males can be found in more diverse habitats, although they tend to avoid areas with high densities of females. In general higher distributions of males can be found in sandy areas near water (Snelleman 2006). The total population of pond bats in the Netherlands is estimated be around 12,000 females and 3,000 males (Haarsma 2009), with female roosts consisting of an average of 132 females and up to 750 individuals and male roosts consisting of an average of 7 animals (Haarsma 2009).

Researchers have employed a combination of survey methods in areas with high and low densities of pond bats. Each survey method differed in its effectiveness in finding roosts. This paper presents an overview of the effectiveness of each of these methods in the hope that it will stimulate more efficient surveying of pond bats roosts. It also provides recommendations for each method and discusses the advantages and disadvantages of each method.

The life cycle of pond bats and a description of different roost types

To optimise the timing of surveys, one needs to consider some details about the life-cycle of the pond bat. Throughout the year, pond bats live in temporary roosts, maternity roosts, male roosts, mating roosts and hibernaculas. For much of the year males and females live in separate roosts and separate areas (Haarsma 2009). In this period each sex mostly roosts in buildings, such as church lofts and hollow walls of houses, although roosts can also be found in trees (Haarsma 2002, Haarsma 2009) and bat boxes (Dieterich & Dieterich 1991, Boshamer 1992, Boshamer & Lina 1999). At other times of the year males and females can be found hibernating together in bunkers, caves and ice cellars (Daan 1973, Masing 1982).

Although apparently very similar to other bats, the life cycle of pond bats is different due their migratory nature (Haarsma et al. 2006) (table 1). Knowledge of this lifecycle is necessary to inform the choice of survey period. Pond bats have a relative short summer season compared to other bat species. In spring, after a short period of living in temporary roosts, female pond bats congregate in "meeting centres": larger maternity roosts in the centre of a group of maternity roosts (figure 1). At the start of May they spread out, to other maternity roosts nearby. Each breeding colony consists of a large group (100–750) of females. At the end of May the first young are born, by mid June the first young can be seen flying outside the roosts. Adult females start migrating to their hibernaculas in the beginning of July and by the end of August nearly all the adult females have left the maternity roosts. On their route to the hibernaculas, usually a distance of between 200 and 300 kilometres, the reproductive females visit a males' mating roost. At the same time, juvenile and subadults cluster in the meeting centre where they will stay until September, with some animals even hibernating in these summer roosts (Haarsma, unpublished observations).

After hibernation, pond bat males sometimes congregate in small groups, but most they live alone. The distance for males between summer and winter habitats averages 70 kilometres (Haarsma 2006), thus effectively they stay in the same area all year round. At the start of August the male groups split up and form separate mating roosts (Haarsma 2003) their reproductive organs swell and the majority become sexually active . They stay in their mating territory until September and then leave to nearby hibernaculas. They may also hibernate in their summer/autumn roosts. Male pond bats remain sexually active throughout the winter, until the beginning of April when their reproductive organs shrink.

Methods

During our pond bat study, carried out between 2002 and 2008, we surveyed most parts of the Netherlands (figure 2). Survey descriptions have been provided in provincial reports (Province of Friesland: Kuiper et al. 2005,

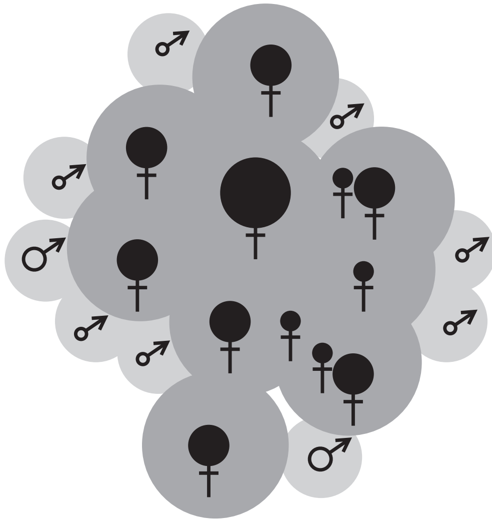

Figure 1. A schematic drawing of the group structure of pond bats in the summer. The female symbols indicate female roost sites, with their foraging habitat shown in dark grey. The male roost sites (male symbols) are located on the edge of the female's summer area. Their foraging areas (light grey) do not overlap with those of the females. The male and female symbols also represent the size of each roost: between 1-65 animals (males) and between 100-750 animals (females). The largest roost (in the middle) is the meeting centre of this population.

Figure 2. Pond Bats in the Netherlands. The grey areas indicate the areas where surveys for pond bats were carried out during the research reported in this paper.

Haarsma 2008a; Province of Gelderland: Haarsma 2008b; Provinces of Zuid-Holland, Utrecht and Noord-Holland: Haarsma 2009; Province of Flevoland: Reinhold et al. 2006, Reinhold et al. 2007; Province of Overijssel: Tuitert & Haarsma 2005; Province of Zeeland: Wieland et al. in press). During these studies, we used five different methods to locate the summer roosts of pond bats: church loft inspections, radio-telemetry, tracking back commuting animals to their roosts, searching for swarming sites and advertising in local papers. In the following section we present a short description of each of these five methods before going on to discuss recommendations for, and the advantages and disadvantages of, each method.

Church loft inspections

Several species of bats can be found roosting in churches (Janssen & Buys 2001). They use the parts not used by humans where warm air accumulates, such as the loft and the tower. Bats can be found by means of visual inspection with a torch, sometimes using binoculars. Some roosting bats hide in crevices and balk joints, though most are found in the centre beam of the church. For monitoring purposes it is common practice to check church lofts between the end of August and the end of September, as this is when the two species that most commonly inhabit church lofts in the Netherlands, *Plecotus auritus* and *Eptesicus serotinus*, are easily visible. However, this period is inappropriate for detecting maternity roosts of pond bats which end to occupy church lofts from between the beginning of May until the middle of July. By August most pond bats have started to migrate to their hibernaculas and left the churches. Annual monitoring of known pond bat roosts in the province of Friesland was performed at the end of June (A.Voûte, personal communication), when the young are large enough to be visible but still easily distinguishable from the adults.

Telemetry

Telemetry is a technology that allows for remote measurement and reporting of information (Wilkinson & Bradbury 1988, Bontadina et al. 1999). The first step is to catch a bat, preferably with mist nets on commuting routes. The bat is then equipped with a lightweight radio transmitter (we used a frequency of 153 MHz, as we wanted to cover a large range) and is then tracked using an antenna and a receiver. A signal can be tracked back to the roost in two ways: tracking the bat all night until it enters the roost in the morning or searching for the signal in daytime. With the second method the researcher waits until daylight and then starts systematically searching all possible sites within a certain area. Within a settlement a signal has an average range of 1 kilometre (depending on the type and quality of the antenna used). This means each city must be searched using a grid-based route of 1 kilometre for a directional antenna or 2 kilometres for an omni-directional antenna.

Pond bats are found flying in their foraging habitats from April to October. In contrast to other bat species, the best period to find a maternity roost of pond bats is from mid-May to the beginning of July and the best period to find a mating roost is from mid-July (males) to mid-September (males and females).

Tracking back commuting routes

Like all bats, pond bats commute over fixed routes between their roost and their foraging habitat (Verboom 1998). In the evening, most bats fly away from the roost, to return in the morning. The direction of the commuting flight can be determined with a bat detector and torchlight (Kelleher & Marnell 2006). On wide canals the sound of pond bats has a very distinctive tonal quality: their normally soft and short FM rhythm lengthens to a louder and longer rhythm with clear FM-QCF pulses around 35 kHz (Boonman & Limpens 1995,

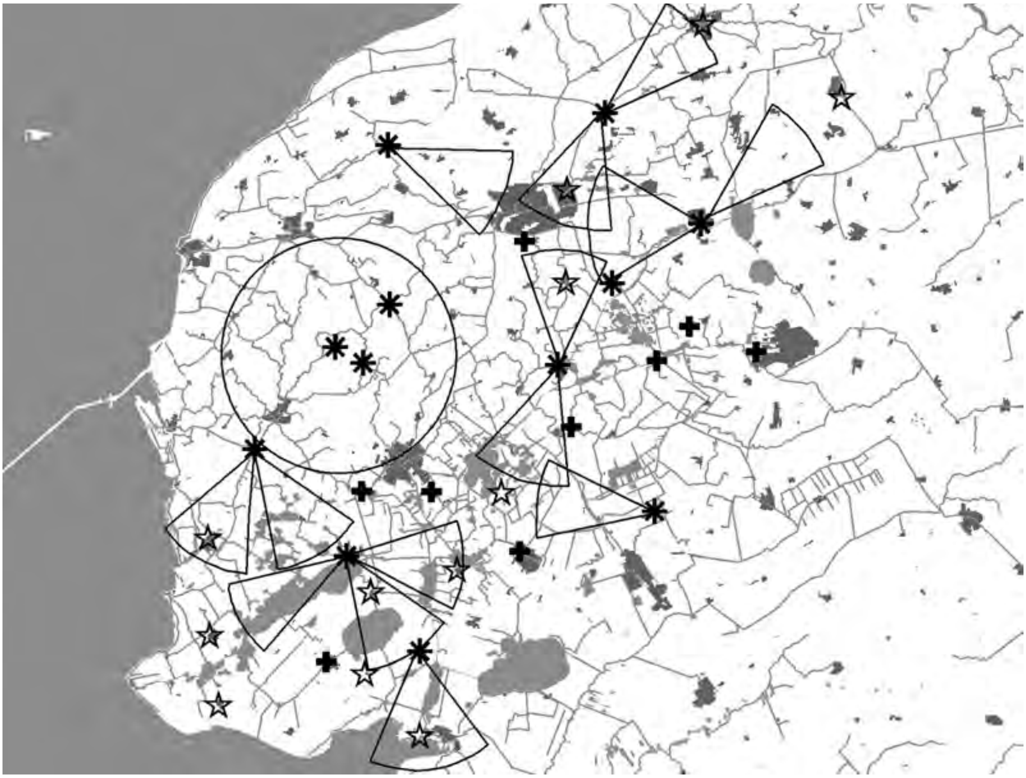

Figure 3. In Friesland data on known roosts was successfully used to estimate the location of unknown roosts. The average distance between known maternity roosts (✳) was 10 kilometres. Each known roost was used as the centre of a circle with a radius of 10 kilometres. Intersections of two or more circles indicate areas with a high probability for discovering a new pond bat roost. The actual locations of the newly discovered maternity roosts are shown with stars (☆) and frequently lie in the vicinity of the intersections of these circles. In some areas, such as the south-western part of Friesland, several smaller roosts were found instead of one large roost. During this research male roosts (+) were also found, although their locations were more haphazard.

Limpens 2001b). These FM-QCF pulses can be heard through a bat detector as very distinctive 'smacking' calls. A bat worker can find the roost by following up the route in the evening or down the route in the morning.

The last part of the route can be difficult to track, as the bats often fly in disparate directions: pond bats often display pre-swarming behaviour above water. Witnessing such activity on waterways before sunset is an indication that there is a roost in the vicinity. By homing in on the centre of activity, it is possible to find the spot where they leave the water and fly over land towards their roost. Pond bats hardly ever use the shortest route to their roost when flying over land. They use bushes, small connecting waterways and darker patches of urban areas. Pond bats cross roads fairly low: at 1 metre above the ground. Sometimes you can find dead bats on the ground close to their roosts, which have been hit by a vehicle (Haarsma unpublished observation, Tuitert & Bode 2000). However, because of their inconspicuous colouring and their small size it is nearly impossible to use these dead bats as an additional method for finding roosts. In some urban areas, pond bats are observed flying high over rooftops (Twisk 1990, Wieland et al. in press). In this manner they can fly in a relative straight line towards their roost without having to avoid streetlights and other obstacles. When flying over land pond bats mostly do not use echolocation, although steep FM pulses can sometimes be heard. Time expansion recordings are needed to avoid confusion with other *Myotis* species. After tracking back a route towards an area the exact location of a roost has to be located by looking for swarming bats.

The best period for tracking back commuting routes of maternity roosts is from mid-May until the beginning of July. Tracking morning routes is better done from June onwards, as temperatures around dawn are still very low in May. From mid-July (smaller) groups of males can be also tracked back.

Searching for swarming bats

It is easy to find a group of swarming bats in front of the entrance of their roost by using a bat detector and a torch (Helmer et al. 1988). Bat detectors can spot a group at a distance of up to 100 metres from the entrance.

Female pond bats swarm in large groups in front of the entrance of their roost, around one hour before dawn. This social behavioural pattern involves groups of several individuals that each swarm for a couple of minutes before entering the roost. The first bats start swarming about 100 minutes before sunrise and the last ones about 40 minutes before sunrise (Voûte & Sluiter 1974), although this can vary greatly according to the weather, the group's reproductive status and group size. On relatively cold nights, when fog spreads over the water, pond bats stop foraging half way through the night and return to their roosts without swarming. Lactating females swarm in much smaller groups throughout the night as they often return to their young to nurse them. The bigger the group, the longer they swarm and the more easily they can be found.

Although 60 minutes swarming seems a relative long period, it is not possible for a researcher to cover an entire large settlement within this period. Therefore this survey method implies a certain amount of planning, based on ecological knowledge (figure 3). Pond bats live in a group structure consisting of several roosts with each roost having its own foraging range. As a result the average distance between two roosts is 10 kilometres, although the exact distance will depend on the quality of the habitat (Snelleman 2006). Where there is a known roost, the 10 kilometre range can be used to estimate the location of an unknown roost; in an urban area this will be somewhere on the edge of a circle with a radius of 10 kilometre from the known roost. In a district with more than one known roost, a more accurate method can be used by using the distance between two (or more) known roosts as the distance range and setting each known roost as the centre of a circle. This allows researchers to identify probable locations of unknown roosts as being either along the edge of the circumference of the circles or close to where two or more circles intersect.

Weather conditions in May are not optimal for searching for swarming bats around dawn. The best period for this using this method is from the beginning of June to the beginning of July. Depending on group size and reproduction status swarming animals can be also found in the middle of the night in mid-June.

Questionnaires or announcements in newspapers

In the early 1960s Sluiter & van Heerdt (1971) found a pond bat roost in a church loft in Kollum, in the province of Friesland. This led them to draw up a questionnaire that they sent to all church committees in the provinces of Friesland and Noord-Holland (Glas 1980). They received many responses, resulting in the discovery of approximately 15 pond bats roosts. However, in the last 40 years pond bats' preferences for roost sites has changed and, instead of mainly using churches, they have started using houses more often (Mostert

Figure 4: Map of location of known male (white circles with black dot) and female roosts (black circles) in the Netherlands. Note that not all areas of the Netherlands have been surveyed (see figure 1). The distribution of female pond bats is related to peat areas (shaded in grey).

1997). Pond bats' fidelity to roost sites and the large numbers of bats that occupy a roost both imply that bat roosts are unlikely to go unnoticed by house owners. Thus during this research, we attempted a variation of the questionnaire approach, this time by posting requests in local newspapers, to try to contact people who had noticed pond bats occupying their house. Although writing a questionnaire or announcement in newspapers seems relative simple, the content of such an article had to be written with care (White et al. 2005). It involved providing a key for recognising pond bats, together with a description of their roosting and flying behaviour. This was to prevent an avalanche of replies from people remembering seeing a bat flying around their shed one evening when they were having a barbeque in their backyard. It is important to describe why such observations are not helpful for bat research.

This method can be utilised all year round, although the best period is the maternity period, from May to June, because then the observations of house owners can be checked. Up to at least two weeks after publishing the questionnaire, somebody has to be available during the day and in the evenings to answer the phone (or e-mails) about bat observations

Results

Total number of roosts found

Prior to 1997 a total of 37 roosts of pond bats were known to exist in the Netherlands (Mostert 1997). Through the joint effort of both the authors and many willing volunteers, we managed to find 35 previously unknown maternity roosts and 49 previously unknown male roosts. Some previously known maternity roosts had been abandoned and some had changed their status to male roosts. By the end of 2008 a total of 59 maternity roosts and 65 male roosts were known to exist in the Netherlands (figure 4). Each newly discovered roost was categorised as either a male or female roost, based on catch results from commuting routes to the roost (only applied with telemetry) or by counting the number of emerging bats. Roosts with more than 100 bats were considered to be maternity roosts, those with fewer than 100 bats were categorised on the basis of catch results.

Effectiveness, selectiveness and efficiency

Over a time period of seven years we used five different survey methods. In table 2 we present an overview of the results obtained with each method and describe them in terms of their effectiveness, selectivity and efficiency (Limpens 2001a). Effectiveness is expressed as the relation between research effort and number of new (male and female) roosts found. The

Table 2. Summary of research results from 2002 to 2008. Fieldwork was carried out in the Provinces of Zuid-Holland, Noord-Holland, Overijssel, Friesland, Flevoland, Utrecht, Gelderland and Zeeland. The effectiveness of the methods used is expressed as the relation between research effort and the number of new roosts found. Only research effort entirely dedicated to finding new roosts is summarised and only the occasions of a newly located pond bat roosts are summarised (sometimes already known roosts are 'refound'). Selectiveness is expressed as the relation between the number of new pond bat roosts found and the number of roosts of other bat species found. The total time spent on each research method can be divided by the number of days spent on preparation and the number of days spent on research. Efficiency is expressed as the relation between the total research time and the number of newly found roosts.

				Effectiveness	Selectiveness	Efficiency	
	Nr of new maternity pond bat roosts found	Nr of new male pond bat roosts found	Nr of already known pond bat roosts found	Research effort	Nr of other bat roosts found	Nr of person-days spent for preparation	Nr of person -days spent for research
Church loft	0	2	0	97 churches	22	14	63
Telemetry	10	19	5	36 pond bats	0	50	130
Tracking back	8	1	1	13 routes	(6)	6	57
Searching for swarming	18	0	0	48 settlements visited	32	5	165
Questionnaire	0	0	0	5 newspapers	6	10	4

more roosts found with a certain fixed effort, the more efficient the method is. Selectivity is expressed as the relation between the number of new pond bat roosts found and the number of roosts of other bat species. With a highly selective method only pond bat roosts will be found, with a less selective method roosts of other species of bats will also be found. The total time spent on each research method can be divided into the number of days spend in preparation and the days spent on research. Efficiency is expressed as the relation between the total research time and the number of new roosts found. The more roosts found in a certain time period, the more efficient the method. The following paragraphs describe the results of each method in terms of these three criteria, taking into account the location (province) and the bat density.

Church loft inspections

Church loft surveys were performed in the provinces of Zuid-Holland, Noord-Holland, Friesland and Overijssel. We visited 97 church lofts, which were strategically selected according by their location near waterways and in an area with recorded pond bat observations. Most church loft visits were performed by two or more people. In Zuid-Holland over 30 churches were visited in search of new pond bat roosts, but the only church where a roost was discovered was not selected for a visit and only discovered through radio-telemetry. In all provinces *Plecotus auritus* was found to be the most common resident of church lofts and a total of 22 new roosts were found for this species. In some churches traces of *Eptesicus serotinus* and *Pipistellus pipistrellus* were also found, but with no indications of a maternity roost.

Use of this method led to just two traces of pond bats being found from (97 visits), neither of which revealed signs of a maternity roost. One church, in the province of Overijssel, was presumably used as a mating site by a small group of males. Another church in the province of Friesland was used by hibernating pond bats, two animals were hibernating between the bricks of the tower walls (Haarsma & Tuitert unpublished data). Other species of bats were occasionally found hibernating in church lofts (Mostert & van der Kuil 1996).

Each church visit requires some preparation (in total 14 days for 97 church visits). We tried two strategies: planning in advance and haphazard visits. Planning a church visit in advance involves making an appointment with the church committee. Finding the phone number of the contact person and convincing them of the importance of the visit is time-consuming. The other strategy, visiting the churches unannounced, also proved to be inefficient. Although neighbours of the church were very helpful in directing us to the contact person, these people were sometimes not home and we had to come back to find them later. We found that it was often easier to convince people to allow us to visit their church through direct contact than by phone. The number of churches that could be visited each day was similar for both strategies: between three and seven per day. A church loft visit takes between 30 minutes (if animals are awake) to 2 hours (if animals are hibernating or hiding in deep crevices).

Telemetry

We used telemetry to search for pond bat roosts in all the regional surveys. Of the 36 radio-tracked pond bats, 29 individuals (10 females and 19 males) were traced to a previously unknown new roost site. Two animals were never found and five animals returned to already known roosts. In Gelderland one male roost was located twice during two different telemetry projects (Limpens 2002, Reinhold et al. 2006). The large home range of female pond bats (over 18 km) twice resulted in the capture of pond bats on a commuting route in Flevoland with the animals subsequently crossing the provincial border and returning to a known roost in Overijssel (Reinhold et al. 2007).

Telemetry involves a lot of preparation, i.e. collecting materials, selecting the most strategic catch position and then actually capturing a pond bat. In total 50 days of preparation was needed in order to radio track 36 animals. The efficiency of telemetry depends on weather conditions, the period of the year, chance and the population density. In areas with high densities of pond bats it takes an average of three hours to capture a pond bat (Kuiper et al. 2005), in other areas it can take up to three days (Reinhold 2007, Haarsma 2008b, Wieland et al. in press). Although some points were visited in advance with a bat detector to check for the presence of pond bats, this did not always result in higher catch efficiency.

After the release of a radio tagged animal a total of 130 days was spent locating the (previously unknown) roosts. This work was mostly done by two or more people, sometimes working in two separate radio-tracking groups. On just four occasions was the exact roost of the animal found during the first night. On eleven occasions the location of the roost was predictable and was found within a few hours of daytime searching. In other attempts, it took some perseverance to find the new roost, and on one occasion a new roost was located on the other side of a 3 km broad and 20 km long water channel (Veluwemeer). This roost took four days to find, although on average it took one day to find a new roost with telemetry.

Tracking back

Most of the tracked back routes were located in Friesland, Overijssel and Zuid-Holland, the only areas with commuting routes carrying a sufficiently large number of bats for an efficient survey. We started tracking back routes of more than fifteen animals, which almost always resulted in us locating maternity roosts of between 100 and 200 animals. In total nine previously unknown roosts and one previously known roost were found using this method. One just three occasions the routes were too diffuse to track back. In addition to locating the roosts of pond bats, roosts of other bat species were also sometimes found, more by chance than because of incorrect species identification. In Gelderland the Vlegel bat group tracked back a route following a group of 15 pond bats (H. Bosch, personal communication, Haarsma 2008b). It took them ten attempts, each involving several people, to locate the roost, showing how labour intensive this approach can be.

Most work on tracking back routes was done as part of the activities of bat groups, and the majority of preparation time was spent on organising the meeting (in total six days for 13 routes). Most track back surveys were performed by several bat workers, each positioned at a strategic position along a potential route. Depending on the number of bats in a group, the number of bat workers and the complexity of the habitat it took between one and five evenings/mornings to track back a route.

Searching for swarming

In Zuid-Holland, Friesland, Overijssel and Zeeland the swarming method was used to search for pond bat roosts. We visited a total of 48 settlements, selected by their strategic location near waterways and their distance from known roosts. Depending on the size of the built up area it took one or several nights to cover a complete area and search for signs of a pond bat roost. In total 18 new pond bat roosts were found, together with an additional 32 roosts of other species. In some highly populated areas with large settlements such as Zuid-Holland, this method yielded no positive results. In Zeeland, where pond bat densities are low, this method also did not score any success (Wieland et al. in press). In Friesland and Overijssel better results were obtained, especially in smaller settlements.

Most searches for swarming were made during meetings of bat groups, and organising these meetings accounted for most of the preparation time (in total 5 days for 48 settlements). Most settlements were visited by two or more bat workers together. Larger settlements were divided in sections, with individual bat workers surveying their own section.

Questionnaire

In the provinces of Zuid-Holland and Friesland we tried using publicity to find new roosts. Although we received many observations of foraging bats and, sometimes, of roost sites (a total of 6 roosts of *Pipistrellus pipistrellus*) this method did not result in us finding any new pond bat roosts. In Friesland we found proof that our publicity actions hadn't reached all roost 'owners'. During a daytime telemetry search, we met homeowners who were curious about the strange antenna on our car roof. After they learned we were searching for bat roosts, they proudly showed us their communal bat roost which held a group of 180 pond bats, inhabiting a complete block of houses and protected by the owners.

The questionnaire method was not very time consuming. After writing and distributing the article, further actions were involved answering phone calls and checking observations. Approximately one out of every ten phone calls needed to be checked during an evening survey.

Discussion

Landscape and population density

The results presented in this paper are based on the Dutch situation. The Netherlands are known for their flatness and being beneath sea level. This is only true of the Dutch lowlands, including most of Holland, other parts of the Netherlands are above sea level and, in some parts, relatively large expanses of (semi natural) forest can be found. The Netherlands is one of the most densely (human) populated regions in Europe (with approximately 16.5 million inhabitants in a country of 45,000 km^2). Hence the Dutch landscape is significantly shaped by human activity, with large intensive agricultural and urban areas and man made waterways. Although the Netherlands is one of the core areas in Europe for the summer distribution of pond bats, the landscape is now quite different both from the ancient landscapes in which populations of pond bats evolved (the arboreal biomes of the temperate humid and boreal zones of the western Palaerctic) and habitats in areas less affected by human activities (for example Poland). The landscape affects pond bat behaviour, such as choice of roosts, habitat use, competition with other species, seasonal behaviour and population density. These factors (urbanisation, number of waterways) need to be taken into consideration when selecting a survey method.

The pond bat tends to show an islet-like distribution throughout its range (Horáček & Hanák 1989), with a few areas of high density within larger territories of low to very low density. This it is worth distinguishing the differences in the efficiency of different survey methods within high and low density territories. In low density areas, such as the provinces of Flevoland, Gelderland and Zeeland, tracking back routes and searching for swarming are more time consuming, as they rely on there being an observable number of bats. In such areas telemetry study is also not very efficient, in this survey it took an average of three days to capture one pond bat (instead of three hours in high density areas). In high density areas, such as Zuid-Holland, Friesland, Noord-Holland and Overijssel, tracking back routes and searching for swarming are very efficient methods. If we exclude effort in low density areas from our dataset it took, on average, five days to track back or find a roost with the swarming method. Thus while these approaches can be used in areas with high and low densities of pond bats, much more time is required in low density areas to achieve similar results. If it is possible to capture pond bats in low density areas then telemetry studies are preferable.

Landscape differences can also cause variations in the effectiveness of different methods. Even within the Netherlands differences in the environment resulted in differences in the effectiveness of different approaches. This can be illustrated by comparing maps of parts of the provinces of Zuid-Holland (figure 5a) and of Overijssel (figure 5b), here shown on the same scale. Each area has about the same density of pond bats, with the mean group size in Zuid-Holland being larger. A major difference between these two provinces is the size of the built up areas (settlements are shown in darkgrey). In Zuid-Holland it is nearly impossible to use swarming as a method for finding pond bat roosts as the settlements are simply too large and telemetry proved to be the most suitable method. In contrast in Overijssel the settlements (mostly villages) are smaller and further apart and almost all of them will contain a pond bat population (Mostert & van Winden 1989, Tuitert & Haarsma 2005, Zoon 2008). So, searching for swarming bats is a very suitable method, because it is possible to cover a complete settlement in one night.

Comparing methods

Sometimes practical considerations will determine the choice of survey method. Such factors might include: the experience needed, the need for licences, the materials required, the duration of fieldwork, the number of people needed, the time needed for preparation and the total cost and available finance. In table 3 we present an overview of these characteristics for each method. Each characteristic is

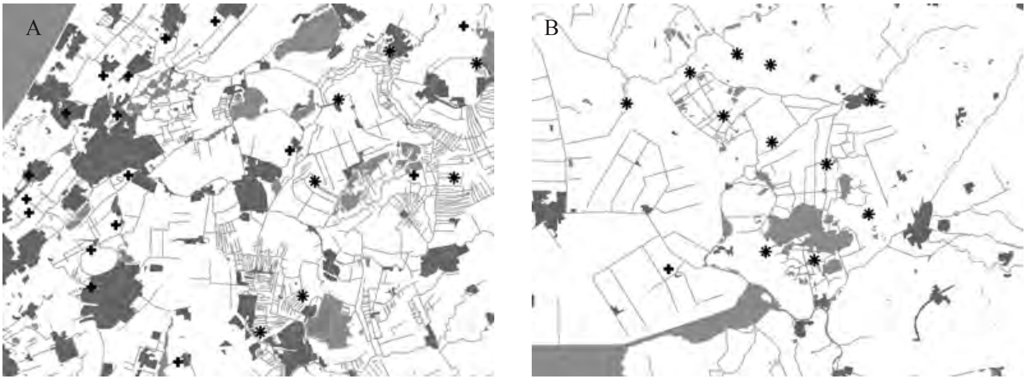

Figure 5. A comparison of two habitats shown at the same scale: A: a detail of the province of Zuid-Holland. B: a detail of the province of Overijssel. Settlements (urban areas) are shaded dark grey, lakes and waterways are shaded in light grey and known maternity and male roost are shown as ✳ and + respectively .

described on a qualitative scale from + (little effort/cost) to +++++ (large effort/costs). Depending on the situation each of these practical considerations can be either an advantage or a disadvantage.

The number of skills a bat worker needed varies between the methods. Relatively little experience is needed for either church loft visits or a questionnaire. Telemetry is the most complicated method, which requires the most experience. In the Netherlands a licence is needed to disturb or catch a protected animal or a (potential) roost of animals. Therefore, telemetry and church loft visits are only possible when one of the workers is in possession of a licence.

The materials needed and the total cost of each method vary greatly. For observing flying bats, i.e. for searching for swarming bats and tracking back commuting bats to the roost, one only needs a flashlight and a bat-detector: relatively standard equipment. For church loft visit a single torch will do. Equally for a questionnaire, one only needs a telephone so that owners of potential roost sites can make contact. However, for telemetry one needs at least bat catching equipment, a radio-transmitter, an antenna and a receiver. This makes telemetry a relatively costly method: one complete set costs approximately € 2000.

The duration and timing of fieldwork are also key considerations . The total time needed for each method depends on several factors, the most important of which are: research period, size of the group of pond bats and complexity of the habitat. In general, the effort required for each method can be ranked as follows (from low to high effort): questionnaire, church loft visits, searching for swarming, tracking back routes and telemetry. Although all the methods can be theoretically performed by one person, they usually involve more people. Two people are needed on church visits for safety reasons. Tracking back and searching for swarming are more effectively performed by two or more people or more and telemetry requires several people to catch the bats and later to track back them back to the roost.

Recommendations for, and the advantages and disadvantages of, each method

Church loft inspections

Recommendations

We recommend dry collecting and storing samples of faeces found when visiting a loft. These can not only be later compared with other reference material of known pond bats but, in future, the species that produced the faeces may even

Table 3. A qualitative comparison of the different methods in terms of the amount of effort required to perform each method (scale ranges from + to +++++. + = little effort/costs, +++++ = large effort/costs, - = not relevant). Each method is described according to the following criteria: experience needed (the level of specific bat work skills required), licence needed (does this method require a licence?), materials used (basic materials or special tools), duration of fieldwork (how many days?), number of people needed (can one researcher manage or are more people needed?), time needed for preparation and total costs (finance).

	Experience needed	Licence needed	Materials used	Duration of fieldwork	Number of people needed	Time needed for preparation	Total costs
Church loft	+	+	+	+	++	+++	+
Telemetry	+++++	++	+++++	+++++	+++++	+++++	+++++
Tracking back	+++	-	++	+++	+++	++	++
Searching for swarming	++	-	++	++	++	+	++
Questionnaire	+	-	-	-	+	+++	+

be identifiable with DNA analyses (Kranstauber 2007). Apart from faeces, any found bat skeletons should be collected; even juveniles can be identified at the species level.

Churches should be visited at the appropriate periods (summer, autumn, winter) when their use by bats can be most expected.. Besides visual inspection with a torch and a pair of binoculars, it is sometimes also possible to inspect crevices with small infrared cameras (Limpens et al. 2006). At present this technique is mainly used for tree roost inspection, but with small adjustments this technique can be used to allow bat workers to look for bats in hollow walls.

Advantages and disadvantages

Pond bats are not always visible in a church loft. For example, one male may use a particular church loft together with other nearby roosts and will leave some traces; grease on frequently used hanging spots and droppings on the ground, but it may be very difficult to distinguish these marks from those of other species.

On one occasion, we found a large group of females (180 individuals) in a church, but they did not use the loft. They formed a breeding colony in the hollow walls and underneath the roof tiles, only leaving their tracks in one corner of the church, where droppings were only found because they fell through a crack between the wall and the church loft.

Although church loft visits are a non-selective method, this can also be an advantage, especially for a study that includes several species of bats. Church loft visits can be performed during the day and does not require a change of day-night rhythm by the bat worker.

Telemetry

Recommendations

We recommend catching pond bats with mist nets at strategically located sites, such as a narrowing section of a waterway. The higher the number of animals expected to pass the better, since catch efficiency is never 100%. We recommend trying to catch several bats so one can then select the bat in the best condition to carry the transmitter (for example the heaviest non-pregnant individual). Unless absolutely necessary for research purposes one should not catch pond bats for telemetry during the end of May, as a high percentage of females are in their last stage of pregnancy and will not be able to carry the extra burden of a transmitter.

For an easy transmitter recovery search, it is recommended to catch pond bats during the beginning of their commuting flights from the roost to the foraging areas (Kuiper et al. 2005). This means within two hours of sunset. This gives an initial indication about the likely direction and distance where one might best search for the roost. During a night pond bats can fly an average of 15 kilometres from their roost. In spring and autumn, when pond bats mostly live in temporary roosts, they are known to have larger home ranges sometimes flying distances of up to 25 kilometres from their roost.

We recommend a mixture of tracking a pond bat back to its roost and searching by daylight, rather than relying exclusively on either method. Due to their speed of flight it can be very difficult to constantly maintain a pond bat within range until it reaches its roost. Taking a few bearings shortly after capture helps identify the direction they are heading and using this information to try to locate the roost in daylight can be more efficient then trying to track an animal all night long. Sometimes researchers can be fooled in thinking they have found a new roost after tracking a pond bat until dawn, only to find that their animal has disappeared the next morning. Pond bats can and do fly during daylight, one particular animal we tracked flew 25 kilometres in the daytime (Reinhold et al. 2006).

Advantages and disadvantages

Telemetry is very effective in finding pond bat roosts. However, the method is not so effective if we take in account that it also quite often leads to the rediscovery of known roosts. During this research in five cases the animals led us to an already known roost. Unlike searching for swarming, with telemetry one never knows where the trail will lead. In addition, the transmitter (or the signal) can sometimes get lost, for example if the bats live in houses with steel roofs, which will almost totally dampen the signal of the transmitter.

Telemetry is a highly efficient method, but also has many disadvantages: it takes a lot of experience to catch and track back an individual. A lot of (expensive) materials are needed, together with different licences to catch, handle and radio-tag bats. The duration of fieldwork is long, as is the time needed for preparation and, last but not least, several people are required during the catching and tracking of each bat. Other advantages of telemetry is that it can also be used to obtain insights in bats' use of habitats and allows one to study differences in behaviour according to gender, age and reproductive status. Similar data cannot be obtained by other currently available methodologies.

Telemetry is also the most selective of the described methods, as the researcher can actively decide which individual to study. Although catching pond bats is an evening job, searching for the roost with telemetry can be performed both at day and at night and the catching and tracking can therefore be combined with a day-time job.

Tracking back commuting routes

Recommendations

To back track commuting routes we recommend starting at strategically positioned spots, such as three-way split of water routes or a main waterway that may provide a corridor between a settlement and a rural area. After observing the main flying direction, the next observation spot should be on the next split of a waterway going back in the direction where the bats came from. We advise taking a map and making relative large steps. Pond bats can fly at speeds of up to 30 kilometres per hour, five kilometres is a ten minutes flight.

The distance between water and roost can be large. We have found breeding colonies where the bats have had to fly more than five kilometres over land, through a highly populated area, to reach the nearest water (Tuitert & Haarsma 2005). If back tracking a route leads to a highly populated area, we recommend switching to telemetry.

Advantages and disadvantages
Although pond bats can be found commuting over waterways almost year round, there are at least four situations in which it is difficult to track bats back to their roosts with this method. Firstly, the distance between bats and the shore may be too large to see the bats by torchlight and without information about the bats' flight direction, the tracking back method is worthless. Secondly, pond bats can use 'quiet sonar'. On frequently used routes, pond bats are known to fly mainly by their memory, hardly using any echolocation (Tuitert & Haarsma 2005) and in such cases a bat detector will be of little use. Thirdly, if the back tracked route ends in a densely populated area it requires great effort by the researcher to locate the roost. A fourth situation in which the tracking methodology becomes less efficient is when pond bats roosting in a settlement use different parallel commuting routes over land from the roost to a nearby waterway, commuting in a diffuse, rather than linear and concentrated, pattern (Limpens 2002).

As with telemetry, tracking back is an indirect method, and tracking back a route can lead to an already known roost.

Searching for swarming animals

Recommendations
The best time for spotting swarming pond bats is just before dawn. We advise using a bat detector and a bicycle to cover a large area within the swarming period, using this method one person can cover 15 hectares. Cycling is faster than walking and gives more mobility than using a car. We recommend using the circle technique, outlined in the method description to select an initial location with the highest potential for pond bats. In the Friesland and Overijssel predictions using this method led to the discovery of several previously unknown roosts. If information on adjacent roost sites is lacking, we advise first surveying waterways as potential commuting routes. Information collected through such surveys, such as flying direction and time of arrival on route, can be used to select the areas with the most potential.

Advantages and disadvantages
Searching for swarming is a direct method and unlike the track back method, the researcher has to select the search area in advance. In a small settlement it is possible to confirm the presence or absence of pond bats in one morning.. If no pond bats are discovered one can visit a neighbouring settlement the following morning. Searching for swarming is a morning job and thus not easily combined with a day-time job.

Questionnaires or announcements in newspapers

Recommendations
An announcement in a local newspaper is much less direct then a questionnaire to a church committee. Although some house owners respond, they were not able to use our guidelines on identifying pond bats. Instead of newspapers, we would recommend using a full colour brochure with information on pond bats and delivering this door to door. Equally setting up an Internet site or giving a lecture to village societies might prove to be successful approaches.

Advantages and disadvantages
Although this method is very cheap and can be performed during the day, it is not easy to obtain the correct information from people. This method needs good public communication skills, which not all fieldworkers necessarily have.

Conclusions

Effectiveness, selectiveness and efficiency

The effectiveness of the methods used varied from no success from a research effort (questionnaire) to highly effective (telemetry). Most studies in which telemetry was applied (29 out of 36) resulted in finding a new roost

With all methods except telemetry other species of bats can also be found, which makes telemetry the most selective method. Church loft inspections are the least selective; they led to the discovery of 22 roosts of other species, but no pond bat roosts.

The efficiency of each method can be calculated by dividing the total number of research days (preparation and research) by the number of (male + female) roosts found (table 2). Telemetry is the most efficient method, taking an average of 6.2 days to find a new roost. Tracking back routes and swarming were the next most effective, taking on average 7 days and 9.4 days respectively. By contrast, church loft visits took an average of 38.5 days and newspaper announcements yielded no positive results.

The total time spent on each research method can be divided into time spent on preparation and time spent on research (table 2). For all research methods, except for the questionnaire, less then 50% of the total time was spent on preparation. For both church loft visits and telemetry more than 15% of the total time was spent on preparation. Searching for swarming bats involves the least preparation time, just 3% of the total time.

We hope that fellow bat workers can use the experience and knowledge, presented in this paper, to their advantage and maximise their chances of finding new roosts with a minimum of effort and costs and that the outcomes of such surveys will enhance the protection of the pond bat throughout its distribution range.

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Samenvatting

Een overzicht en evaluatie van methoden om zomerverblijfplaatsen van de meervleermuis (*Myotis dasycneme*) op te sporen

Gedurende een langlopend en intensief onderzoek naar de meervleermuis (*Myotis dasyc-*

neme), uitgevoerd op verschillende plaatsen in Nederland, hebben we vijf onderzoeksmethoden toegepast om verblijfplaatsen te vinden: kerkzolderinspectie, telemetrie, het terugvolgen van vliegroutes, het zoeken van zwermende dieren in de ochtend en oproepen in de media. In dit artikel geven we voor elke van deze methoden een overzicht van de benodigde materialen en van de timing en duur van het onderzoek. Daarnaast geven we enkele praktische adviezen. De gebruikte methoden gaven verschillende uitkomsten met betrekking tot effectiviteit, selectiviteit en efficiëntie om een verblijfplaats te vinden. Om de verschillende methoden met elkaar te kunnen vergelijken hebben we per methode het aantal dagen dat besteed moet worden aan voorbereiding en onderzoek om een nieuw verblijf te vinden naast elkaar gezet. Met behulp van kerkzolderinventarisaties duurde het gemiddeld 43,5 dagen om een nieuw verblijf te vinden, met telemetrie 7 dagen, het terugvolgen van vliegroutes 7 dagen en ochtendzwermen 9,4 dagen. Elk van deze methoden vereist een specifieke ervaring, materialen en vergunningen. De haalbaarheid van een methode is afhankelijk van het onderzoeksdoel en van het levensstadium van de vleermuis. Verschillende combinaties tussen genoemde onderzoeksmethoden zijn mogelijk. Met dit artikel hopen we een handvat te bieden voor toekomstige onderzoeksinventarisaties.

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