Tunnels as a possibility to connect bat habitats

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ABSTRACT
Fragmentation of the landscape is one of the greatest problems for animals which use large home ranges and/or different habitats within a landscape. Even in the case of undisturbed hunting habitats and roosts, disconnection of flight paths could lead to a decline in the populations of bats. Tunnels connecting both sides of a barrier, allowing exchange, can be used to minimise the impact of e.g. motorways. Results of studies in different parts of Germany and anecdotal observations in other parts of Germany demonstrate the use of tunnels for nine species of bats. Data are analysed with respect to different types of tunnels. Although our data do not allow quantitative analysis, observations suggest smaller bats like *Myotis nattereri*, and *M. daubentonii* can use relatively low and narrow tunnels, whereas the larger *M. myotis*, was only observed using larger tunnels. The results support the role of tunnels as effective for the conservation of the connectivity of landscapes.

KEY WORDS
Chiroptera,
landscape planning,
motorways,
mitigation possibilities.

RÉSUMÉ

Possibilité de connecter les habitats des Chiroptères par des tunnels.

La fragmentation des paysages est un problème majeur pour les animaux qui utilisent de larges domaines vitaux et/ou différents habitats. Même avec des habitats et des gîtes protégés, la rupture de leurs routes de vol peut entraîner le déclin de populations de chauves-souris. Les tunnels, en permettant les échanges entre les deux côtés d'une barrière, peuvent minimiser l'impact des autoroutes, par exemple. Des études conduites dans plusieurs régions d'Allemagne, ainsi que des observations ponctuelles dans d'autres régions, ont révélé l'utilisation des tunnels par neuf espèces de chauves-souris. Ces données sont analysées en fonction des différents types de tunnels. Bien qu'elles ne se prêtent pas à une analyse quantitative, il ressort que les espèces de petite taille, *Myotis nattereri* et *M. daubentonii* notamment, peuvent utiliser des tunnels longs et étroits, alors que le Grand murin *M. myotis*, n'a été observé que dans les grands tunnels. Ces résultats confirment le rôle effectif des tunnels dans le maintien de la connectivité des paysages pour les chauves-souris.

MOTS-CLÉS
Chiroptères, aménagement du paysage, autoroutes, tunnels.

INTRODUCTION

In view of European and especially German legislation on nature conservation and environmental impact assessment (EIA), and recognising that bats are good indicators in complex landscape relations, it is required (and beneficial for both bats and nature conservation in general) to consider bats in planning. Planning authorities have the legal responsibility to consider negative effects and to assess and mitigate environmental impact as part of the planning process. As required in German and European law (e.g. the European Habitats Directive), bats need to be studied in an EIA, when new and relevant information for the planning of the project can be expected (Brinkmann *et al.* 1996; Brinkmann & Limpens 1999). As a result bats have indeed been integrated in several planning processes during the last years. The authors and a team of colleagues have been working with bats in several different EIAs in order to estimate impact on bats and propose mitigation in these specific cases, as well as to be able to actively develop practical procedures for bats in EIA in different planning situations (e.g. Brinkman *et al.* 1996; Limpens & Roschen 1997; Bach *et al.* 1999; Brinkmann & Limpens 1999; Rahmel *et al.* 1999; Bach 2002).

Motorways provide a negative impact on nature and the environment (Reck 1990; Kiefer & Sander 1993; Bairlein & Sonntag 1994; Klenke *et al.* 1996). One of the problems for bats is the interruption of flight paths. In three combined EIAs for a planned motorway in the German federal state of Hessen, the authors identified a total of 41 (potential) interruptions of flight paths of at least five species (*Myotis myotis, M. nattereri, M. brandtii/mystacinus, M. daubentonii* and *Pipistrellus pipistrellus*) along a stretch of about 25 km of planned motorway. The planned motorway will also disrupt 45 hunting sites of eight species.

With the exception of *Myotis emarginatus,* all bat species in Germany are identified as traffic victims (Richarz 2000). Thus, roads and motorways may very well be considered barriers for bats on their flight paths from the roost to their hunting sites, and a risk especially where bats try to cross roads low above the ground (see also Dietz 1993; Pir 1994). Building of tunnels or green bridges is suggested as a possible solution to these conflicts in the planning of motorways.

Only a few observation on the use of tunnels and/or bridges as connective elements by bats have been published (Richarz 2000). For many bat species it was, and still is, not definitely known whether they would really use such constructions.

In suggesting mitigation measures, therefore for many bat species we can only predict whether they might be expected to use such mitigation measures from the analogy with the behaviour of other species. For detailed and specific planning of mitigation, collection of available (anecdotal) observations of the use of tunnels and/or bridges by different bat species, as well as systematic studies addressing this topic are needed. Here we present some preliminary data from different investigations, where it has been possible to study the use of tunnels by bats. With the preliminary data in this paper we try to address the questions: Which bat species are known or observed to use tunnels to cross large roads? And, which bat species are known or observed to use bridges to cross motorways? In addition we try to discuss whether from available information a possible relation between the size (width, height, length) of a tunnel and the species using it, could be deduced.

METHODS

Data were extracted from different investigations in Hessen and Würzburg (Lüttmann *et al.* 2002) (Germany). Both localities are in the forest in central and south Germany.

In Würzburg three tunnels of the motorway A3 and A81 were investigated in August 2001 to find out whether *Myotis bechsteinii* would use tunnels to cross motorways. Two of the tunnels were situated between the town of Würzburg and an old beech forest. The third tunnel connected two forests. The tunnels were investigated by two persons per tunnel on five nights from half an hour before sunset to sunrise, with a break between 1:00 and 4:00 o'clock. The bats were identified using Pettersson D240 and D240x bat detectors (heterodyne and time expansion), allowing observation and recording. All passing bats were recorded and the sound tracks were analysed afterwards using the Pettersson BatSound 3.2 system. To enhance visual observation in identification of *Myotis bechsteinii* and other species, we also used an image intensifier (Leica BIG5 2175).

In Hessen a total of eight motorway tunnels and five bridges of the motorway A4 were studied by two persons (one per tunnel/bridge) from May until August in 2001 (8 tunnels and 1 bridge) and in 2002 (1 tunnel and 4 bridges). Two bridges and five tunnels connected villages to forests or farmland with hedgerows, whereas the rest connected two forests. Each construction was studied one night by visual and auditory observation during one year from half an hour before sunset to sunrise. Species were identified using a Pettersson D240 and D240x bat detectors (heterodyne and time expansion). Simultaneously to these visual and auditory observation, other tunnels or bridges were checked with automatic "bat registration boxes" (SSF-Bat-detector, alarm clock, voice active Olympus Pearlcorder S 728). Short pulse sequences (= 10 pulses) on the bat-boxes were counted as "passing through", whereas longer pulse sequences (> 10 pulses) were counted as "hunting".

In addition to these systematic and targeted studies we collected a number of unsystematic observations on nine tunnels from different EIAs in forest-dominated midlands of northern Hessen between 1997 and 2000. Here the tunnels were not studied all night nor in different parts of the season, but observations only tried to check whether the tunnels were used and by which species.

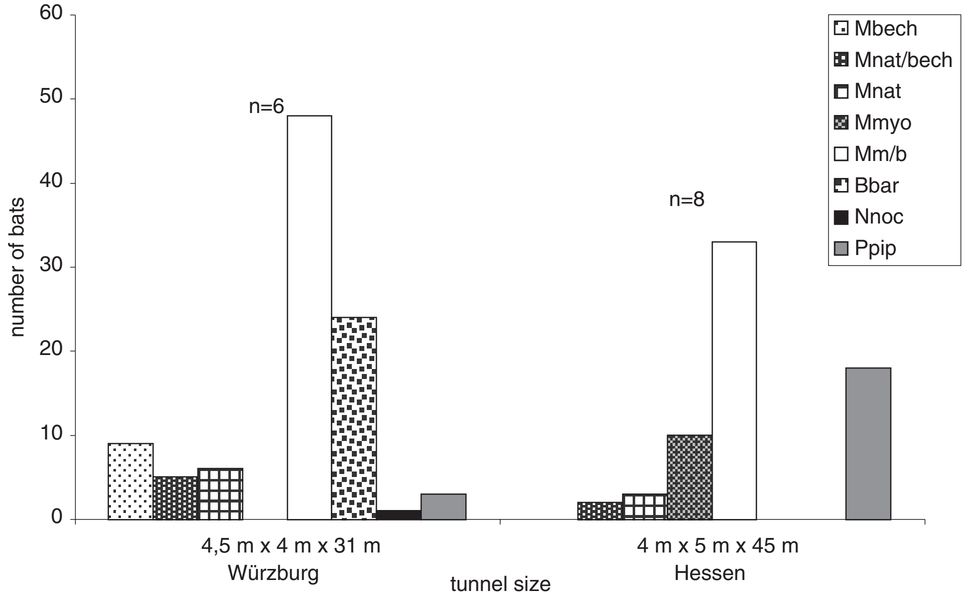
Because the study area in Hessen contained four bridges and nine tunnels distributed over a length of 17.5 km, a qualitative comparison will be made between the passing through tunnels and over bridges. Statistical comparison is not allowed, since the bats on these flight paths come from different roost with different numbers of animals.

RESULTS

TUNNELS

In Würzburg five species (*Pipistrellus pipistrellus, Myotis nattereri, M. bechsteinii, Barbastella barbastellus, Nyctalus noctula*) and *Myotis brandtii/mystacinus* were found flying through tunnels of 4,5 m wide, 4 m high and 31 m long (Fig. 1A).

A



B

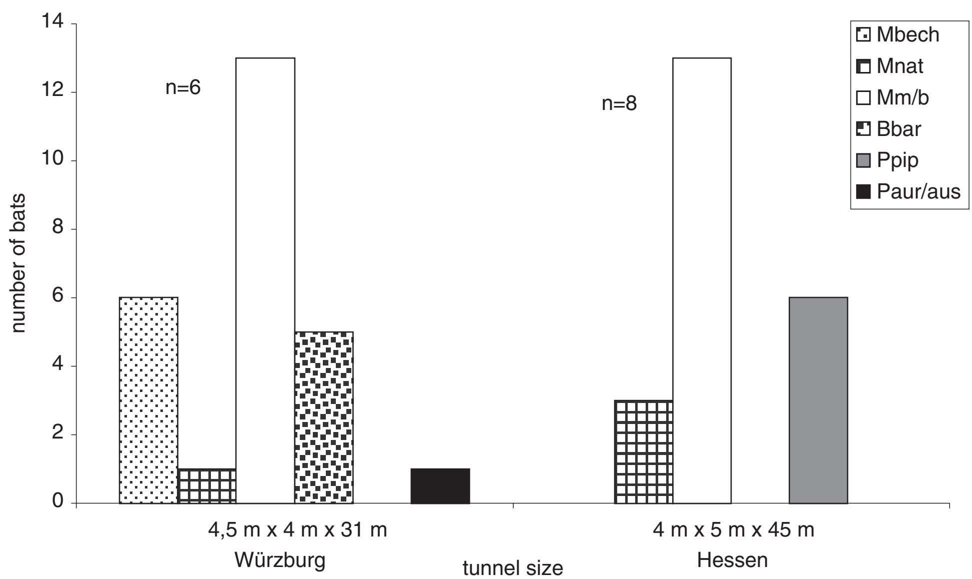


FIG. 1. — Number of bats at two study sites in Würzburg and Hessen; **A**, passing through tunnels; **B**, hunting in tunnels. **Mbech**, *Myotis bechsteinii*; **Mnat**, *M. nattereri*; **Mmyo**, *M. myotis*; **Mm/b**, *M. mystacinus/brandtii*; **Bbar**, *Barbastella barbastellus*; **Nnoc**, *Nyctalus noctula*; **Ppip**, *Pipistrellus pipistrellus*; **Paur/aus**, *Plecotus auritus/austriacus*; **tunnel size**, height x width x length; **n**, number of tunnels.

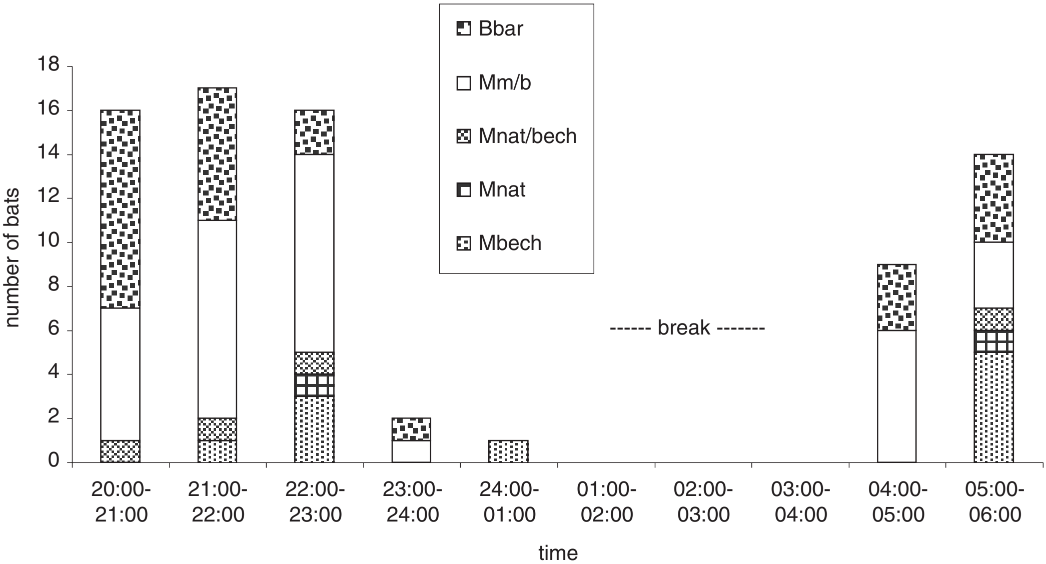


FIG. 2. — Bats passing through the tunnel "Schenkensee" (4.5 m x 4 m x 31 m) during the night in Würzburg. **Mbech**, *Myotis bechsteinii*; **Mnat**, *M. nattereri*; **Mm/b**, *M. mystacinus/brandtii*; **Bbar**, *Barbastella barbastellus*.

Myotis brandtii/mystacinus were most frequent, followed by *Barbastella barbastellus, Myotis bechsteinii, M. nattereri*, and *Pipistrellus pipistrellus*. Also one individual of *Nyctalus noctula* was observed flying through the tunnel. Observations concentrated in the first and last 1,5 hour of the night, indicating use of the tunnels during commuting flight towards their hunting sites or back to the roosts again. But, as figure 2 shows, bats were also passing through the tunnel throughout the night. The sixth species (*Plecotus auritus/austriacus*) was only observed hunting in the tunnel.

In Hessen four bat species (*Pipistrellus pipistrellus, Myotis myotis, M. nattereri, M. bechsteinii*) and *Myotis brandtii/mystacinus* passed through the tunnels (4 m wide, 5 m high, 45 m long). Again, *Myotis brandtii/mystacinus* was observed most frequently, followed by *Pipistrellus pipistrellus, Myotis myotis* and *M. nattereri* (Fig. 1A).

All the tunnels were also used as hunting sites by a total of four bat species (*Pipistrellus pipistrellus, Myotis nattereri, M. bechsteinii, Barbastella barbastellus*), and the two sibling pairs *Myotis brandtii/mystacinus* and *Plecotus auritus/austriacus*. Most commonly *Myotis brandtii/mystacinus* were observed hunting inside the tunnels. *M. bechsteinii, Pipistrellus pipistrellus, Barbastella barbastellus* and *M. nattereri* were hunting in the tunnels to a lesser extent (Fig. 1B). The bat registration boxes, used in Hessen, registered only three bat species or species pairs (*Myotis brandtii/mystacinus)* passing through (Fig. 3) and three bat species and *Myotis brandtii/mystacinus* hunting in the tunnels (Fig. 3).

Most of the nine tunnels unsystematically surveyed in northern Hessen connected villages to forest or farmland with hedgerows. Even though results from different tunnels are not comparable, due to differences in observation protocols, and differences in connecting structures, it is obvious that all tunnels were used by bats. In addition to previous results some *M. daubentonii* and *Plecotus auritus/austriacus* could be observed passing through tunnels (Fig. 4).

One of the most interesting situations was in Ulfen, where a tunnel of only 1.5 m wide and

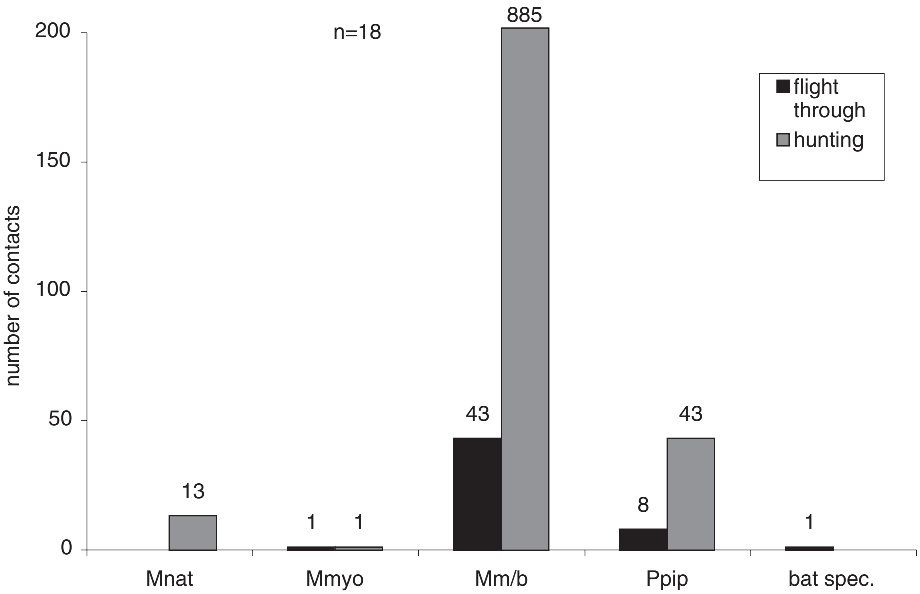


FIG. 3. — Bats passing through and hunting inside eight tunnels (5 m x 5 m x 45 m) in Hessen counted with bat registration boxes. **Mnat**, *M. nattereri*; **Mmyo**, *Myotis myotis*; **Mm/b**, *M. mystacinus/brandtii*; **Ppip**, *Pipistrellus pipistrellus*; **bat spec.**, undetermined bat; **tunnel size**, height x width x length: 5 m x 5 m x 45 m; **n**, investigated nights.

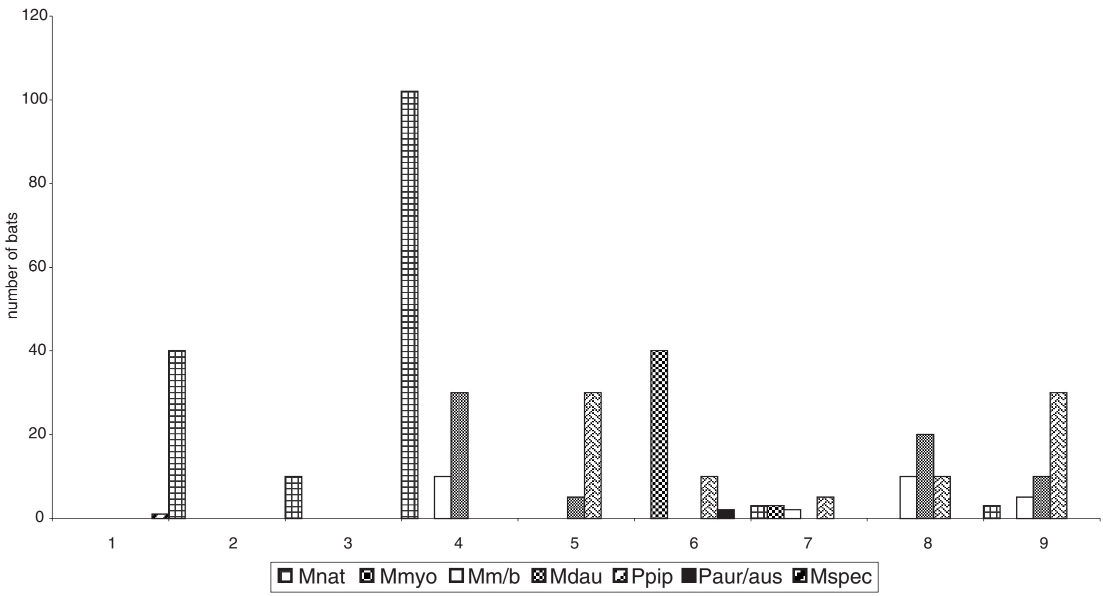


FIG. 4. — Unsystematic observations of bats using tunnels of different sizes in Hessen. **Mnat**, *M. nattereri*; **Mmyo**, *Myotis myotis*; **Mm/b**, *M. mystacinus/brandtii*; **Mdau**, *M. daubentonii*; **Ppip**, *Pipistrellus pipistrellus*; **Paur/aus**, *Plecotus auritus/austriacus*; **Mspec.**, *Myotis* sp.; **tunnel size**, height x width x length; **1**, 2 m x 1.5 m x 50 m; **2**; 1.5 m x 2 m x 30 m; **3**, 1,5 m x 1.5 m x 15 m; **4**, 2 m x 2 m x 2 m; **5**, 4 m x 15 m x 45 m; **6**, 6 m x 5 m x 40 m; **7**, 3.5 m x 5 m x 25 m, **8**, 3 m x 10 m x 15 m; **9**, 2.5 m x 4 m x 15 m.

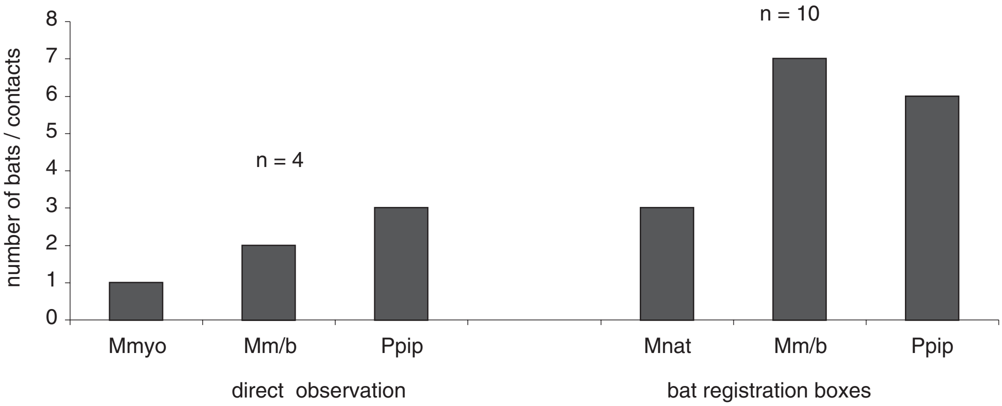


FIG. 5. — Number of bats/bat contacts passing over bridges in Hessen. **Mnat**, *M. nattereri*; **Mmyo**, *M. myotis*; **Mm/b**, *M. mystacinus/brandtii*; **Ppip**, *Pipistrellus pipistrellus*; **n**, number of bridges.

2 m high with a length of 30 m connected both sides of a broad crossroad. There was also a small stream flowing through the tunnel. The tunnel was in the direct vicinity of a maternity roost of *M. nattereri* and about 40 of the 45 bats in the roost used that tunnel to cross the road.

BRIDGES

In 2001 and 2002 a total of five bridges were investigated. All bridges connected forests or hedgerows leading to a village or a forest. Only three species (*Pipistrellus pipistrellus, Myotis myotis, M. nattereri*) and the sibling pair *Myotis brandtii/mystacinus* were observed to use the bridges and in very low numbers only (Fig. 5).
In comparing passages through tunnels and over bridges in the study area in Hessen (Figs 1A; 5) we find that less bat species use bridges to cross the investigated motorways and the numbers of bats using the tunnels is higher than those using bridges.

DISCUSSION

In central Europe motorways are an important factor in the fragmentation of landscapes. One possible solution mitigating fragmentation by large roads, are tunnels and bridges. Three small systematic investigations along the A3 and A81 in Würzburg and along the A4 in Hessen demonstrate that at least six bat species and the sibling pair *Myotis mystacinus/brandtii* regularly use tunnels while commuting along their flight paths in the evening and morning, but also while changing from one hunting site to another during the night. These tunnels were built for forestry and agricultural vehicles. *Nyctalus leisleri* and one *Nyctalus noctula* were also observed to cross the motorway high up in the air. Unsystematic investigations of nine other tunnels demonstrated that *Myotis daubentonii* and *Plecotus auritus/austriacus* also regularly used tunnels to cross roads.
These data correspond with results of e.g. Krull *et al.* (1991) and Brinkmann *et al.* (2002), who observed *Myotis emarginatus* flew longer distances to use a tunnel for crossing a motorway, rather than taking the shortest way and flying over the motorway. Similar results were found for brown long-eared bats (*Plecotus auritus*) (Fuhrmann 1991), Daubenton's bats (*Myotis daubentonii*) and Pipistrelle bats (*Pipistrellus pipistrellus*) (Häusler & Kalko 1991). Pond bats (*Myotis dasycneme*) were observed to cross through tunnels and above smaller water courses crossing underneath motorways in the Netherlands (Limpens *et al.* 1997). In Germany Schikore & Zimmermann (2000) observed pond bats to use culvert to cross

the A27 in Niedersachsen. In an experiment a tunnel construction was built in Switzerland to test the reaction of *Miniopterus schreibersii* (Lugon pers. comm.). He found that the tunnel was used by *Miniopterus schreibersii* and *Myotis myotis*. In northern Germany the authors also observed *Eptesicus serotinus* to regularly use tunnels.

A small series of observations on a total of 15 tunnels, viaducts and bridges crossing a large motorway in the Netherlands in 2002, demonstrated that those structures were used by *Myotis daubentonii, M. nattereri, Pipistrellus pipistrellus,* and *Plecotus auritus/austriacus.* Daubenton's bats predominantly used situations where a small stream flowed through a small tunnel to cross underneath the motorway. *P. pipistrellus* and *Eptesicus serotinus* were also observed to cross the motorway alongside bridges, sometimes flying above bridge level, but also close to the bridge at the street level of the bridge. Although the data do not allow quantitative analysis, the observations suggest the avoidance of illuminated tunnels (see also Alder 1993).

Our results, together with data from the literature, show that tunnels, and for some species even relatively small tunnels, can minimise the fragmentation effect of large roads such as motorways, when they are situated at the right places. Although our data do not allow quantitative analysis, observations suggest that *M. nattereri*, and *M. daubentonii* already use relatively low (1.5 m) and narrow (2 m) tunnels, even if they are long (> 30 m). *M. daubentonii* will do so especially when a stream is flowing through the tunnel. Other species tend to use (or are observed only in) larger tunnels, especially the larger *M. myotis*, which was only observed to use tunnels more frequently when they were at least 3.5 m high. Other factors, such as the vicinity of a roost, and the location of the different tunnels in relation to roosts and hunting sites may very well bias this impression. Bat conservation and mitigation practice, however, calls for a thorough analysis of the relation of factors such as tunnel size, their location in relation to roosts and hunting habitats, the way they are connected to bat habitats, illumination, traffic in the tunnels and their use by bats and different species. In preparation of such studies it is of importance and interest to collect as much anecdotal information as possible on the use of tunnels and/or bridges to cross barriers.

To summarise available data, we can demonstrate that at least eleven bat species and two sibling pair use tunnels of different sizes to cross large roads. Although relatively low and narrow tunnels can be used it seems that larger bats like *M. myotis* prefer larger tunnels. In contrast, only five species of bats and one sibling pair are known to use bridges. Fuhrmann & Kiefer (1996) described a experiment to save flight paths of *Myotis myotis* crossing a planned road line in front of the colony. They built a bridge-like construction directly in front of the roost and found that the bats accepted that construction as a new flight path. In contrast to that, the bridges in our studies in Hessen were not at all, or only little used by bats, even when they were well connected (with hedgerows) to the landscape on both sides of the bridge. It might be possible that the bats find these bridges "too open", lacking guiding or sheltering vegetation or structure along the bridge. Possibly in such open situations even the light of the traffic has an inhibiting effect for bats such as the *Myotis* species. There is a need to experiment with a kind of "green bridge", where e.g. a forest road and a part with bushes are combined. Such construction might optimise the bridges for bats. Existing green bridges should be checked regarding their use by bats.

Nevertheless tunnels seem to suit bats better to pass from one side of a motorway to the other. They are not inhibited from using narrow and long tunnels, and they even hunt in the larger ones. This result might not be surprising considering the narrow and long passages in hibernation sites that bats inhabit during winter. In order to assess available (anecdotal) knowledge on if and how bats use tunnels and bridges to cross motorways, we would like to invite everybody to share their knowledge and send us their information.

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