Technical Guide No. 1

Systems to help with the crossing of roads

Intergrated conservation and management
of two bat species
The Greater Horseshoe Bat and Geoffroy's Bat
in the Mediterranean region of France

LIFE+ CHIRO MED Program
2010-2014

LIFE+ Chiro Med

is a Life*+ "Nature and Biodiversity*"
Dedicated specially to two species of bats :

The Greater Horseshoe Bat and Geoffroy's Bat

Cover photo : T. Stoecklé.

Contents

Bats, mammals that testify to the state of the biodiversity

From their position in the food chain, bats are good indicators of the ecological status of natural habitats.They are in effect directly impacted by the alteration of the ecosystems* in which they live. They are the flag bearing species* whose conservation involves many issues where man has a role to play.

In the course of the XX[th] century the numbers of the 34 species identified on French metropolitan territory has vastly declined. Their rapid regression has aroused, for the last few decades, an interest from naturalists and scientists who seek to better understand the problems which weigh against them. The improvement in knowledge of these problems, as well as that of the biology of the ecology of bats, allowed them to propose methods to protect them. These methods are put in place on a case by case basis or within the framework of larger programs (The Regional Action Plan in favour of bats) and for the last few years has given positive and encouraging results and reinforces the continuation of scientific and technical research.

A strong concentration of the species in the south of France

Metropolitan France houses 34 of the 41 bat species present in Europe, of which a third are threatened or near threatened[1] because of the change in their environment. The Mediterranean, the Rhone Valley and the Alps have the highest diversity.For example, the regions of Provence-Alpes-Côte d'Azur and Languedoc-Roussillon Coast are home to 30 species.But these regions also have the highest proportion of threatened species at national level. The responsibility for these regions in terms of conservation is paramount.

Services rendered* to man, and unsuspectedly, from bats

- **An economic and health issue :** All species of European bats are insectivores. They eat tons of insects during the night including some pests of cultures[2]. They therefore play a natural and free regulating role in the control of insect populations and thus contribute to reducing the purchase and use of pesticides. A study Science has been able to estimate the economy of the U.S. agriculture could reach 53 billion dollars[3].

- **A natural fertilizer :** Bat guano is a powerful natural fertilizer because of its high nutrient content.

- **Recent scientific research into future medical issues :** The special morphology and physiology of bats are studied in many fields of medical research into new technologies for the exploration of body by imaging, and are providing solutions on viral outbreaks and cancers[4].

[1] According to the International Union for Conservation of Nature (IUCN) and the National Museum of Natural History (NMNH). 2009.
[2] Jay M., Boreau de Roncé C., Ricard J.-M., Garcin A., Mandrin J.-F., Lavigne C., Bouvier J.-C., Tupinier Y. & S. Puechmaille. 2012. Biodiversité fonctionnelle en verger de pommier : Les chauves-souris consomment-elles des ravageurs ? *Infos CTIFL*, 286 : 28-34.
[3] Boyles J. G., Cryan P. M., McCracken G. F. & T. H. Kunz. 2011. Economic importance of bats in agriculture, *Science*, vol. 332 (6025) : 41-42.
[4] Zhang G. *et al.* 2013. Comparative analysis of bats genomes provides insight into the evolution of flight and immunity. *Science*, 339 (6118) : 456-460.

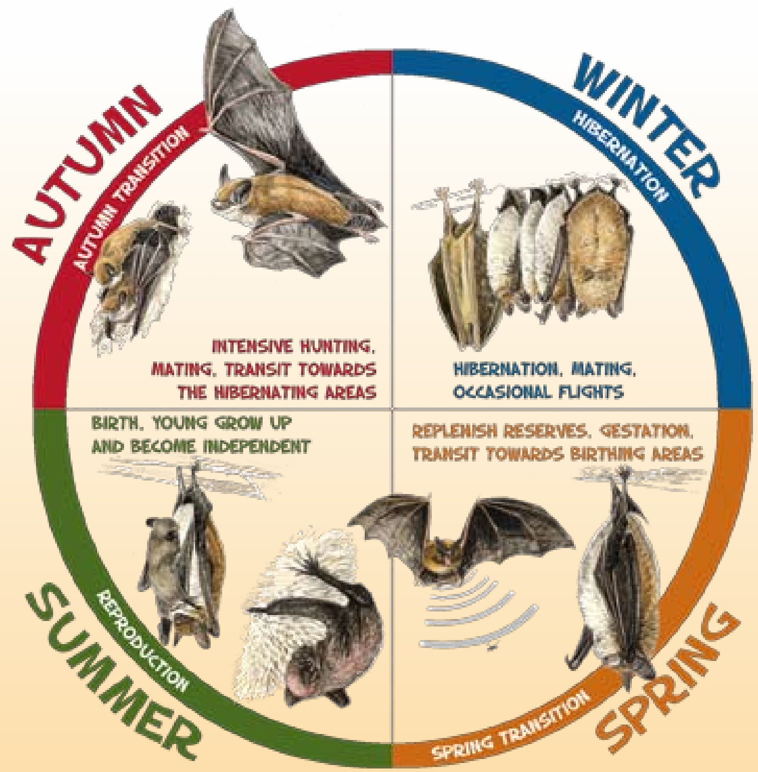
All bats are protected by law by means of :

- **International law,** by the Bonn Convention and the Berne Convention signed in 1979 and ratified by France in 1990. And by the agreement "EUROBATS*", created in 1991 and ratified by 31 countries, which commits signatory states to implement a concerted protection of the populations of bats from the European continent.

- **European Union law,** by Annex IV of the "Fauna-Flora-Habitat" Directive* (92/43/EEC) of 21 May 1992 dictates that all species of bat need of strict protection. Twelve species in France are listed in Annex II of the Directive, which lists species of community interest whose conservation requires the designation of Special Zones of Conservation (SZCs). Thus, bat populations, including their roosts and their habitats* were included in the designation of sites of the European Natura 2000 network.

- **French national law,** by Article L.411-1 of the Environmental Code and the Ministerial Decree of 23 April 2007 (Official Journal of 10/05/2007) which establishes the list of terrestrial mammals protected throughout the country and the terms of their protection. The new law now protects all species of bats currently present in metropolitan area by name, as well as the protection of breeding sites and resting places of the species, necessary for the proper performance of their life cycles.

A very specific life cycle



THE GREATER HORSESHOE BAT

The Greater Horseshoe Bat (*Rhinolophus ferrumequinum*) is the largest Horseshoe Bat in Europe. The main feature of this species is the morphology of his nose, decorated with a leaf-shaped horseshoe essential for echolocation.

Longevity : 15 to 30 years
Size : about 7 cm
Wingspan : 33 to 40 cm
Weight : 15 to 34 g
Coat : brown, more or less a type of red (dorsal) and grey-white to yellowish-white (ventral)
Ultrasound : between 79 and 84 kHz (Frequency Constant)

Reproduction : Females reach sexual maturity at 2-3 years. Their mating, in autumn, is accompanied by a winter sperm storage in females. Ovulation occurs when the sunny days return. Then their gestation lasts between 6 and 8 weeks, with a maximum of 10 weeks when spring is particularly unfavorable. From mid-June to late July, they give birth to one young per year which learns to fly at between 19 and 30 days, and is autonomous at 45 days.

Movement / Migration : A sedentary species, the Greater Horseshoe Bat rarely moves more than 100 km between breeding roosts* and hibernating roosts* passing through one or more transit roosts* (known maximum distance of travel 320 km).

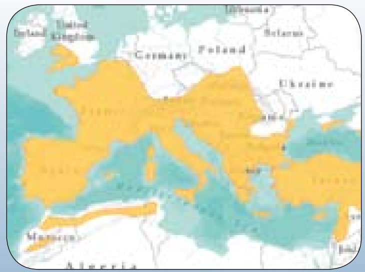
T. Stoecklé

Roosts : In summer, females settle in small groups in warm cavities (21-30°C) and often in buildings(barns, attics, hot cellars, roofs of churches, bunkers...) abandoned, maintained, or new, to give birth and raise their young until emancipation. Males generally pass summer alone.
In winter, the species hibernates from around October-November to April in natural or artificial underground cavities (mines, quarries, caves or cellars) which possess total darkness, a temperature between 5°C and 12°C, humidity at saturation, light ventilation absolute tranquility. These bats hang by the feet (typical of Rhinolophidae).

Hunting Grounds : Essentially wooded (riverine woodland, deciduous forest) and pastureland's surrounded by hedges. Hedgerows are very important for their resources of prey on one hand and also especially as travel corridors on the other (*see* Technical Guide No. 5 "Elements of area conservation management").

Diet : In general, the species feeds on dung beetles (beetles and dung beetles) and nocturnal Lepidoptera, but can also consume Orthoptera (grasshoppers, crickets), Trichoptera, flies, spiders, etc. (*see* Technical Guide No. 5 "Elements of area conservation management").

Distribution : Populations have much reduced in the northwest of Europe during the last century, sometimes completely disappeared (Belgium, Netherlands, Malta) **The epicenter of the European** distribution is in the **Mediterranean basin**.



Map source : IUCN (International Union for Conservation of Nature) 2008. *Rhinolophus ferrumequinum. In* : IUCN 2013. IUCN Red List of Threatened Species.

GEOFFROY'S BAT

Geoffroy's Bat (*Myotis emarginatus*) is medium in size with a distinct indentation, almost at right angles to the outer edge of his brown ear. His coat has a dense woolly appearance, red on the back, lighter on the belly (not much contrast).

Longevity : up to 18 years
Size : about 4-5 cm
Ears of medium size : from 1.4 to 1.7 cm
Wingspan : 22 to 24.5 cm
Weight : 6 to 15 g
Tragus* : sharp and does not reach the top of the notch in the ear
Ultrasound : begins at 140 kHz and ends to 38 kHz (Frequency Modulated Steep)

Reproduction : Mating take place in autumn. The females store sperm until spring. Ovulation occurs when the warm days return, and birth of one single young per year takes place between mid-June and late July, after 50 - 60 days of gestation. The youngster is capab e of flying at the age of 4 weeks.

Movement / Migration : A largely sedentary species. The distances between summer roosts and winter roosts is generally less than 40 km (maximum known movement : 105 km).

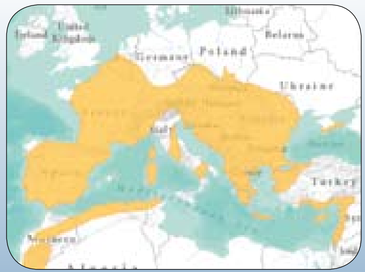
Roosts : The breeding roosts are mainly attics or lofts but can be barns, caves, or bunkers as in the Camargue, temperate (23-27°C). Females congregate in swarms of 50 to 600 individuals. Males generally pass summer alone. In winter, the species hibernates in caves, quarries, mines and large caverns which have total darkness, a relative humidity close to saturation, temperature below 12°C and almost no ventilation.

B. Morazé

Hunting Grounds : Mainly forest or wooded areas, deciduous or mixed. However this species also exploits parks and gardens, large isolated trees or small patches of vegetation, stables, pastures, groves, areas above rivers and also, in the Mediterranean, traditional olive groves, coniferous forests and orchards (*see* technical Guide No. 5 "Elements of area conservation management").

Diet : Very specialized, it is composed mainly of spiders, harvestmen and flies, supplemented by Coleoptera, Hemiptera and Neuroptera. In the Camargue there is a local particularity as it is composed mainly of spiders and Odonata, an abundant food resource in the area (*see* Technical Guide No. 5 "Elements of area conservation management").

Distribution : The species shows a very heterogeneous distribution over its entire range. In France there are strong disparities depending on the region. **The south of France** has a low population in winter but a **high population in summer**.

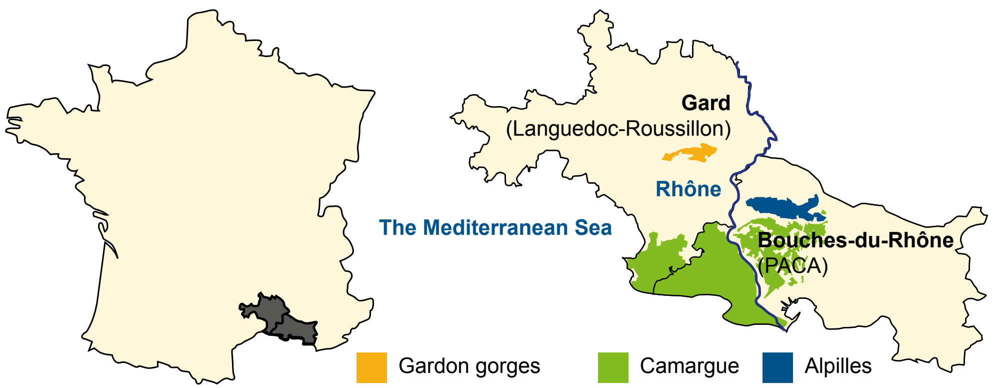


Map source : IUCN (International Union for Conservation of Nature) 2008. *Myotis emarginatus. In* : IUCN 2013. IUCN Red List of Threatened Species.

THE EUROPEAN LIFE+ CHIRO MED PROGRAM (2010 – 2014)

The LIFE+ Chiro Med program (www.lifechiromed.fr) focuses on the conservation and integrated management of two species of bats, the Greater Horseshoe Bat and Geoffroy's Bat, in the French Mediterranean region. The objective of the program is to understand and to preserve each required biological compartment necessary for the annual cycle of local populations of the two targeted species. The strong anthropisation of targeted territories and interactions between the species and humans necessitates an implementation of concerted actions, most importantly close to human activities.

The program focuses on three geographic areas, the **Camargue**, the **Alpilles** and the **Gardon gorges**, and eight sites of community interest, called CIS. In effect in the French Mediterranean region, the main populations of the two species targeted by the program are concentrated in these three territories. In winter, these species hibernate in the cavities of the Gardon gorges and the Alpilles, while in summer they come to feed and reproduce in the Camargue.



The program allows, through 29 actions, to unite technical competence and territorial jurisdictions to overcome the **five major threats to these species :**

- *Threat 1* : the loss and alteration of hibernation and breeding roosts.
- *Threat 2* : the loss and alteration of habitats used as feeding sites (hunting grounds) and travel corridors.
- *Threat 3* : dwindling food resources related to the use of pesticides and modification of agro-pastoral practices.
- *Threat 4* : road deaths.
- *Threat 5* : an ignorance of bats which generates unintended destruction.

To address these threats to the two target species also means protection a large number of other species and their habitats. These are referred to as "umbrella species".

BATS AND INFASTRUCTURE

Public politics in favour of biodiversity

Green and Blue Network

The Green and Blue Network (Trame Verte et Bleue in French TVB - www.trameverteetbleue.fr) is a key measure of the Grenelle Environment (I and II) with the objective of halting the loss of biodiversity. This objective is also part of the political commitments of France, notably within the framework of the National Strategy for Biodiversity 2011-2020 (SNB - www.developpement-durable.gouv. fr/-La-Strategie-nationale-pour-la-.html).

The restoration of these ecological continuities is essential

It involves implementing means to initiate, promote and facilitate the recovery of an ecosystem that has been degraded, damaged or destroyed by human activity.
This restoration work may be :
- Maintaining existing landscape features (hedges, trees, other structures),
- replant hedgerows,
- remove barriers to ecological continuity,
- create artificial corridors as a last resort.

The central idea of the TVB is to create a "Ecological infrastructure" ensuring the communication between the areas of living and of reproducing of the species (namely reservoirs of biodiversity). Its principle rests on the service and the restoration of ecological continuities (The corridors*) between these reservoirs in the scope of a regional diagram of ecological consistency (SRCE)*. This diagram is based on a shared diagnosis of issues around preservation and the rehabilitation of ecological conditions and is mapped to 1/100 000. The Green network corresponds to areas of vegetation and the Blue network to water courses.

Line of hedges, near the roost of a colony (Camargue), used by the bats.

T. Stoecklé

"Black" Network

Like the green and blue networks, the grid of spaces without lighting compared to artificially lit spaces constitutes the black network.

Alignment of lamps creating a barrier effect. © E. Cosson

Like many species, bats are active only at night. The development of artificial lighting induces behavioral changes in these mammals. These changes may be temporarily profitable for some species such as the pistrelles who hunt around lampposts which have attracted insects. The fact remains that the resources of prey dwindles because of these lights. However, in species such as rhinolophs, behaviors correspond to a negative phototaxis, this is to say, a repulsion to light. They shun the light in particular to stay invisible to predators.

The presence of lighting can thus lead bats to abandon a flight route and its associated hunting grounds, reducing the home range of individuals and the colony. **The light is therefore in itself an infrastructure** that can be impassable for certain species. Bats seem to always avoid light when they are not hunting. The lighting infrastructure (buildings, roads, etc.) and headlights can thus form real barriers for these species and have significant impacts on populations of bats (*see* box below).

The consideration of this issue by legislators is very recent. It has resulted in **the Grenelle 1 laws (art. 41) in 2009 and Grenelle 2 (art. 173) in 2010**, which highlight the need to take into account the impacts of artificial light emissions on the landscape and the environment, and imposes the need to prevent or mitigate threats or excessive problems to the environment caused by these lights. These requirements were introduced in the Enviromental Code by Article L583. According to **Decree No. 2011-831 of 12 July 2011** on the prevention and limitation of light pollution, more restrictive measures are provided in natural protected areas : national parks, nature reserves, regional marine parks, Natura 2000 sites, to limit all the consequences of light pollution affecting biodiversity. In addition, **the Decree of 30 January 2013** (which came into force on 1 July, 2013) regulates the operation of lighting systems for non-residential buildings to reduce energy consumption and the footprint of artificial lighting on the night environment.

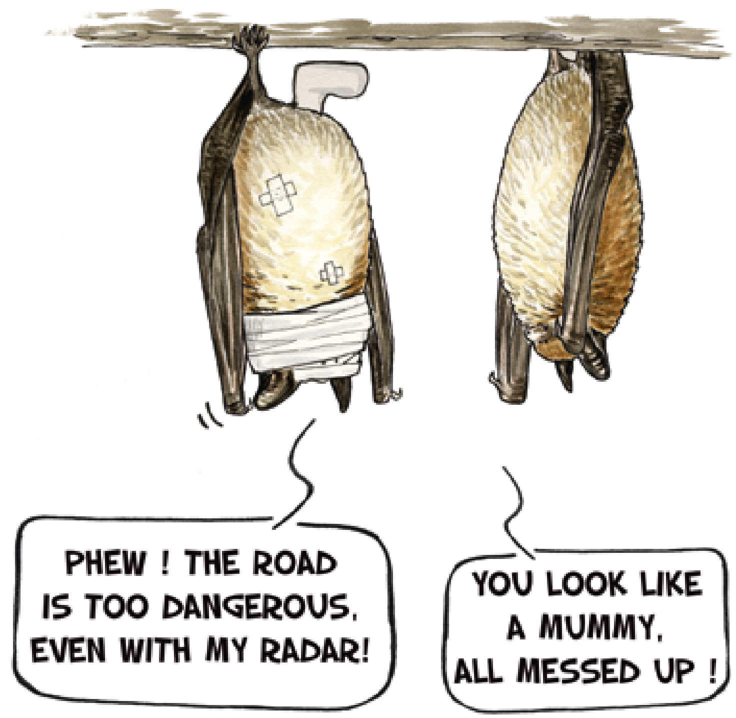
The theme of light pollution was not studied directly under the LIFE+ Chiro Med program but it is a factor present locally which was taken into account in the implementation of actions.

Light pollution, a tool to protect bats ?

Studies are underway to show the "repellent" side of artificial lighting and to use this phenomenon to create a barrier on the edge of road zones where there is a high risk of road collision in order to divert bats to safer crossing zones.

Impacts of road infrastructure on bats

The infrastructure of passenger and goods transport (roads, railways...) allow the operation and the economic and social development of the country but this multiplicity of transport networks has resulted in the fragmentation of natural areas*.



The transport infrastructure causes three major problems for bats

- **Breaking flight routes** : linear infrastructures are barriers that lead to fragmentation of populations.
- The **loss of hunting grounds and roosts** linked to the direct destruction of vegetation and associated food resources (insects) at the point of the infrastructure or the abandonment of certain hunting grounds which have become inaccessible.
- The **direct destruction of bats** through collision with vehicles.

National doctrine: avoid, reduce, compensate

Within the framework of administrative authorization procedures or in the absence of them,

at the request of the prefect of the region, all developers* must ensure a project design with the minimum impact on the environment. In such, the priority is to **avoid** major environmental impacts. As well as this, if the negative environmental impacts could not be fully avoided, they must be **reduced** as much as possible, including through the mobilization of technical solutions for minimizing the impact at a reasonable cost[5], in order to achieve the lowest residual impacts possible. Finally, if a significant adverse impact remains, they are to consider how to ensure appropriate **compensation** for this impact by implementing a consideration of at least the equivalent, feasible and effective, to a scale relevant to the territory.

The implementation of this compensation does not eliminate the impact on the bat and its habitats* linked to the successful completion of their life cycle (roosts, corridors , hunting grounds) by the project. Thus, under Articles L411 -1 and 2 of the Environmental Code, a special procedure, involving the National Council for the Protection of Nature (NCPN) remains essential in considering the pursuit of the project.

IN BRIEF

The transport infrastructure is a major cause of mortality, of consumption of natural areas, but also a barrier that inhibits the movement of mammals, including bats that do not move on the ground.

Projects to build new roads, highways, railways clearly require studies of the habitats (roosts, hunting areas, corridors), the presence of populations and their movements in order to understand and preserve local bats and to estimate the impact of these developments on the balance of the affected ecosystem.

The developer must best adapt his project in the context of the environment to limit the impacts on biodiversity and possibly propose appropriate measures to maintain and development bat populations suffering from its effects.

Objectives of the LIFE+ Chiro Med Program

The program aims to **provide innovative and effective tools to help bats safely pass over infrastructure** and more generally to participate in the improvement of ecological connectivity* between the different life compartments of bats (roosts for transit, hibernation, mating and hunting).

[5] The law does not specify the cost but the National Doctrine (Doctrine ERC - http://www.developpement-durable.gouv.fr/Doctrine-eviter-reduire-et,28438.html), which is an interpretation of the law, indicates the need to implement technical solutions to minimize impacts at a reasonable cost.

This guide relates the experiences gained during the LIFE+ Chiro Med program in relation to actions to reduce road deaths (Threat 4) and to improve the transparency of road infrastructure in respect to bats (Threats 2 and 5).

The actions of the LIFE+ Chiro Med program were oriented along the following lines :

Objectives	Related Actions
1 - What is the effective and actual mortality in the study area ?	A6
2 - Can we identify areas of road conflict / bats ?	A6
3 - What are the behaviours of bats at these points of conflict ?	A6
4 - What innovative mechanisms can be developed to eliminate these points of conflict ?	C3
5 - What are the behaviours of bats in the presence of experimental devices ?	E5

FOR MORE INFORMATION

The reader may refer to the SETRA guides « ***Routes et Chiroptères*** » for more information on the measures to mitigate the impact of road infrastructure in relation to the bat.

For example :

- avoid the periods of high sensitivity to bats,
- avoid bat "traps" such as a hedge or a woodland along the edge of the roadside,
- design a project by integrating a network of hedges / woodland and riparian forests so as to improve the permeability of the infrastructure,
- provide screens or coverings* in corners to avoid dissemination of headlights to the surrounding natural environment
- etc.

The **Camargue - Crau - Alpilles - Gardon** area is an zone that combines a variety of natural habitats and species and a high level of urbanization and transport network development. This dynamic has led to the creation of a dense network of roads and railways and the appearance of a diffuse and extensive urban fabric.
This has caused a fragmentation of the landscape that hinders the biological cycle of many plant and animal species, including bats.

*The **RN 113**, which connects Arles to Saint-Martin-de-Crau, coupled in its southern part by a main road and its northern part by a railway and the RN 453, represents a **significant barrier** for populations.*

To date, the RN 113 has not been subject to any road crossing device to restore the ecological continuity between north and south. © I. Biren & J. Namy

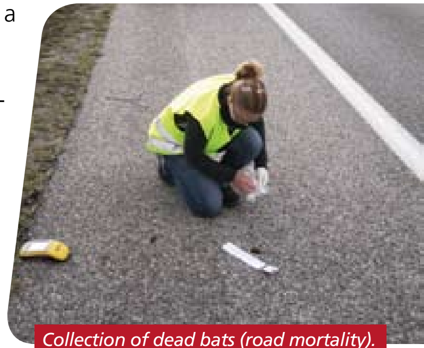
Moreover, the proposed motorway bypass of Arles (A54) envisaged by 2017, will for half of it (~ 13 km) be a new route to the south of Arles agglomeration creating a further discontinuity between the Camargue and the Alpilles, the other half of the project consists of a development on the current site of the RN113 at Saint-Martin-de-Crau (redevelopment of the network).

The work of the LIFE+ Chiro Med program has already allowed developers to better assess the effects of their infrastructures and integrate new solutions during the entire A54 project. Indeed, an additional environmental study was scheduled to complete the preliminary studies of wildlife in general, and Chiroptera in particular (landscape proposals , arrangements of works, dedicated bridges, etc.) On the section of the RN113 in development, there are more than 6 supplementary facilities on OA that were projected.

The current state of knowledge in the Camargue and the Alpilles reveals a population of **800 Greater Horseshoe Bats** and **1,500 Geoffroy's Bats** during the breeding period, before birthing, divided into 11 colonies, about **¼ of the breeding population in the PACA region**. These two species of bat are a major reproduction pool for the population of the border regions. The conservation of the populations of the Camargue-Crau-Alpilles-Gardon sector is of multiregional interest because of its potential ability to support other neighbouring populations.

Road deaths

Although difficult to estimate, the direct destruction by collision with a vehicle appears to be the most visible effect of roads on wildlife.

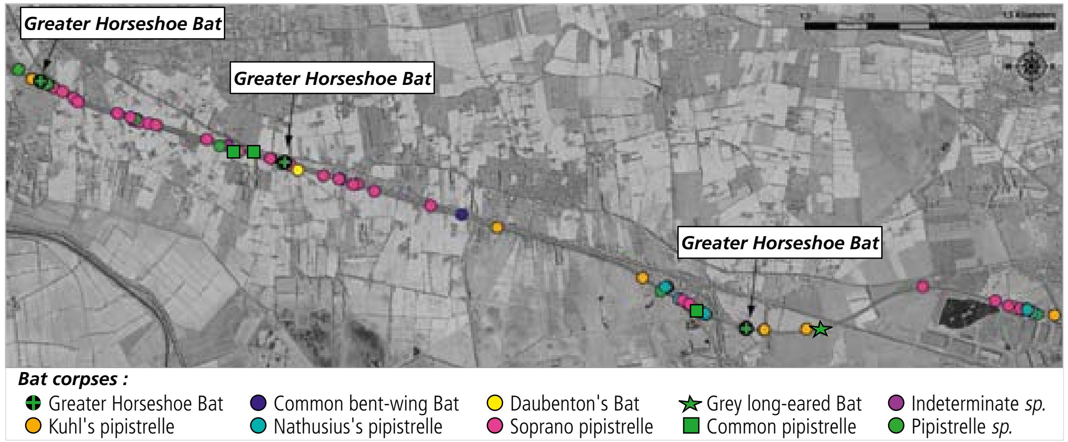

Collection of dead bats (road mortality).
© I. Biren & J. Namy

Several authors consider that road mortality is strongly underestimated. Indeed, the corpses of bats found in searches on the roadside, only represent a small proportion of animals actually killed. Because of their small size, bats are usually left attached to cars or are projected outside the edge of the roadway. Finally, scavengers (birds of prey and smaller carnivores but mainly ants and wasps in the study area) eat a significant percentage of bats hit during the night. The areas where there is a concentration of corpses on the road or rail are identified as conflict areas or "black spots". Young bats less experienced in flight are often most affected. Locally, in a protected area of the Alpilles hibernating populations of Greater Horseshoe Bat diminished after the construction of the A54 at Crau despite the strict and effective protection of the main roosting site which initially hosted 400 individuals in 1989, and less than 100 currently. No breeding population exists in the Alpilles and genetic analysis shows the close link between the animals in the Camargue during summer and those of the Alpilles in winter. Although the cause and effect is not provable, it remains highly probable and consistent with what has been observed in relation to Rhinolophides vis-à-vis road deaths.

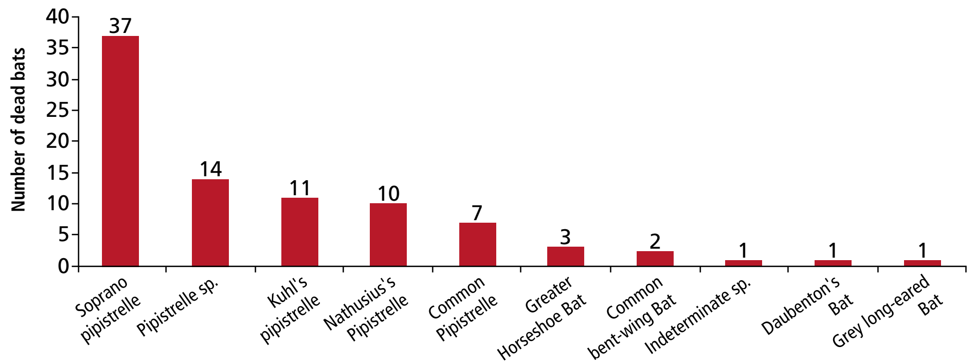
Under the LIFE+ Chiro Med program, a study of the mortality of bats was conducted on a section of the RN113 between Arles and Saint-Martin-de-Crau in late summer 2010 (*see* report LIFE+ Actions Chiro Med). This road is a duel carraigeway limited to 110 km/h, oriented east-west, which is a significant barrier between several ecological entities namely Alpilles to the north, the Camargue and the Crau south. At the time of the study, the entire curtain of large trees located between the railway and the RN113 Raphèle-les-Arles to Pont -de-Crau had been deforested .

The LIFE+ Chiro Med in numbers

The RN113 is used by an annual average daily number of 80,000 vehicles and has little permeability for wildlife.
Under the program, the CEREMA (ex CETE) and the DIRMED collected bat corpses for 3 days per week from September 2 to October 13, 2010. It focused on a portion of 14 km in both directions of movement. 108 dead animals were collected, of which 88 were bats, therefore 95% (5 individuals of species from Annex II of the Directive "Fauna-Flora-Habitats" :
3 Greater Horseshoe bats and 2 Common bent-wing bats, but no Geoffroy's bats.



Location of dead bats on the section studied on the RN113 Arles / Saint-Martin-de-Crau (14 km) under the LIFE+ Chiro Med program (02/09/2010 to 13/10/2010).



Assessment of numbers of each species of bat found on the section studied RN113 Arles /Saint-Martin de Crau (14km) under the LIFE+ Chiro Med program (02/09/2010 to 13/10/2010).

The majority of cases of mortality concern the pipistrelle, slightly ahead of the Greater Horseshoe Bat. It should also be noted that, despite the presence of Geoffroy's Bat around the RN113, no individual of this species were discovered in the mortality study at the end of summer, however, this species was found dead in the same area under the wind turbines at Saint-Martin-de-Crau. For the ecological functioning of the population of Greater Horseshoe Bat in the Camargue-Crau-Alpilles-Gardon sector, the RN113 is a major obstruction all along the life cycle of individuals and it is a proven threat by direct destruction (collisions).
The three cases of mortality of Greater Horseshoe Bat could not be related to a particular element of the landscape. In contrast, mortality concentrated in other species was often linked to the presence of plantations nearby, or even in contact with or overhanging the roads, along which the animals hunt, especially during windy periods.

For animals that were sexed, the sex ratio was balanced and 90% of individuals were young. For the Greater Horseshoe Bat we collected two young females and one individual of indeterminate sex and age. After five years of intensive study, we do not believe there is a breeding colony close to the RN113, the first known colony is located 12 km away.

The areas most deadly to all species generally correspond to the following situation :

1. An **intersection between a road and a wooded corridor frequented by bats in transit**. The majority of bats use the landscape elements to track (hedges, borders, etc.). When they must cross an open space, they tend to fly closer to the ground, probably because of ultrasonic parameters (especially in plecotus and rhinolophus that have a short-range sonar), because they are less visible to predators the heat renders the soil more attractive to insects. In the case of crossing a road the bats are then just at the height of the vehicles.

2. A **woodland strip or hedge running along a roadside, popular with hunting bats**. Often bats that hunt along borders make return trips. Where woodland ends at a road they can be required to turn over the road surface, exposing themselves to the vehicles in circulation.

3. When the previous two cases do not explain the location of the animal killed, we believe that the **absence of appropriate road underpasses and adequate overpasses** forces animals to risk a dangerous or fatal crossing. Note that there are only five overpasses in the 15 km east of the Camargue to cross the RN113. They are risky for bats due to vehicles using them.

4. It also seems that cases of deaths grouped in space and time can be explained by **herd behaviour** by a group of bats or exploitation by several individuals of a wealth of insects located near the road, even above the road surface. This phenomenon has been observed occasionally on the RN113, on the RD570 (6 pipistrelles killed one evening on a specific point in 2013, but not observed during the monitoring in 2011) and also seen in the mortality caused by wind turbines in Saint-Martin-de-Crau (a group of the same species on the same day under the same wind turbine).

IN BRIEF

The local environment appears to have an important role in the characteristics of the sectors where mortality is high. A comparative study of mortality within an area of suburban and hilly highway (west of Toulon) showed almost no mortality of bats. Mortality is exacerbated when the context of the landscape is preserved when the route is level with the natural terrain and / or where underpasses are rare and inadequate, hence the importance of preserving and developing overpasses in this context.

Road collision mortality is very serious for the bat population and ultimately could affect the state of conservation of local populations.

Diagnosis must be made and solutions found to reduce the pressure that traffic routes place on bat populations.

Identification of road black spots

The objective of this section is to identify points of conflict between bats and roads, ie road black spots, using various methods and comparing their efficiency.

The method is organized into four complementary procedures implemented successively :
- analysis of the results of telemetry,
- a theoretical analysis by mapping,
- a validation in the field by deploying automatic ultrasonic detectors along roadways,
- a further validation in the field by direct observation using a thermal camera and occasionally a night vision monocular to identify flight directions of bats in transit.

Methods used

Telemetric monitoring

Flight routes and crossings points over roadways were identified through the results obtained during 60 nights of telemetry divided into 4 sessions during the summers of 2010 and 2011 of 34 Greater Horseshoe Bats and 25 Geoffroy's Bats (report A5).

Different phases of telemetry : transmitter used (0.38 g), radio-tracking and mapping exercise. @ V. Hénoux

Telemetry consists of following a bat previously equipped with a transmitter (centre photo) using Yagi antennas and radio receivers (pictured left). The position of the bat is determined by triangulation of azimuths simultaneously on reception of a signal (pictured right). This technique allows us to know the movements of equipped individuals and locate their hunting grounds, their roosts and their flight tracks. This method is very technical in its implementation but provides unique and high-quality results.

Cartographic analysis

In parallel, a **cartographic examination** of landscape structure was made from aerial photos (linear corridors, etc.) within a radius of at least 1.5 km around the reproducing colonies. Following the mapping of hedgerow networks conducted in 2010 under other actions of LIFE+ Chiro Med (A5 and C4), the intersections between the hedges or channels and roadways have been completed and marked as **potential crossing areas for bats** (see maps and report A6).

Automatic ultrasonic detector AnaBat™. © E. Cosson

Automatic detection by ultrasound

Previously identified crossings were refined and validated by the use of **automatic ultrasonic detectors** (AnaBat™). These devices can measure bat activity (number of contacts) and therefore the zones with a higher density of passing bats , including the Greater Horseshoe Bat, whose identification may be made by automatic filter, which is not the case with Geoffroy's Bat. The latter belongs to a group of species specified here as Murines type Frequency Modulated steep High Frequency.

Direct observations by thermal camera

To clarify the **behaviour of bats** on crossings identified by the mapping and audio method, **direct observations** were conducted using a night vision monocular and especially a FLIR SC660 thermal camera.

The aim was to verify the actual passage of bats and their flight directions (sometimes animals went along roadways or retraced their tracks and the acoustic analysis could not detect them), only direct observation could validate passages over roadways, and help understand the crossing behaviour of the animals. These observations, made repeatedly during the annual cycle, represent a zero state and will be valuable to develop devices to assist with road crossing and subsequent evaluation.

Thermal camera © T. Stoecklé

Results

Telemetry helped highlight areas of travel and hunting grounds used by the breeding colonies of Greater Horseshoe Bats and Geoffroy's Bats in the Camargue in summer (A5). These transit routes are rough in most cases but highlight night after night, the roads most frequently flown.

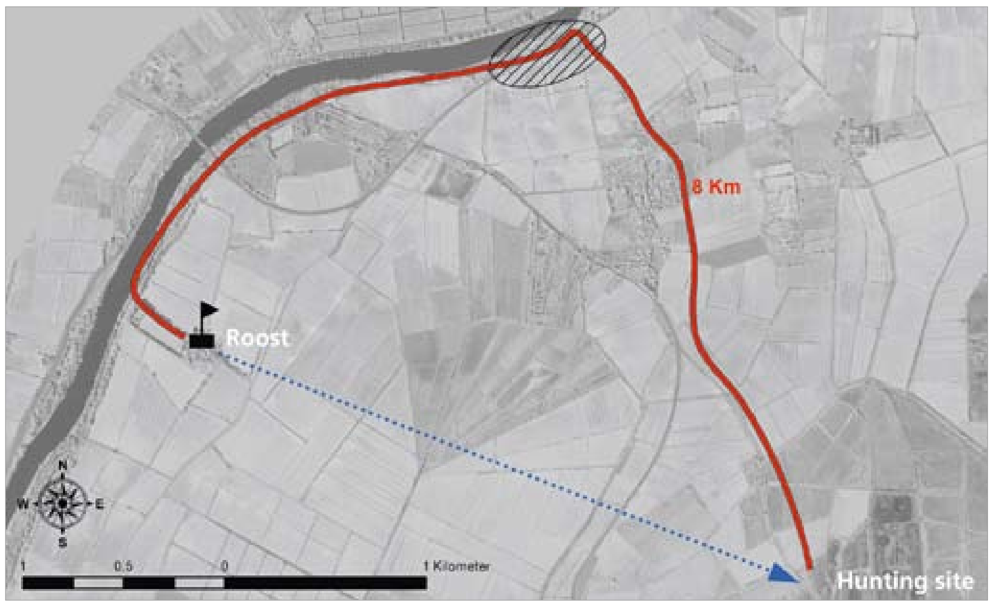
The LIFE+ Chiro Med in numbers

On the roads of Bouches-du-Rhone, 80 potential black spots were identified around seven breeding colonies.

Over 40 of these black spots have been subject to a study with automatic ultrasound detectors.

Nine of these points revealed a large enough presence of Greater Horseshoe bat to conduct behavioural observations.

The map below illustrates the transit of two individuals who passed on several consecutive nights northwards to get to the southeast of the colony in the Bernacles marsh and Mas Julian. The red line marks the route of flight proven during telemetry. These individuals have followed the Rhone, crossed the highway and then crossed agricultural areas to reach the marsh where they hunt.

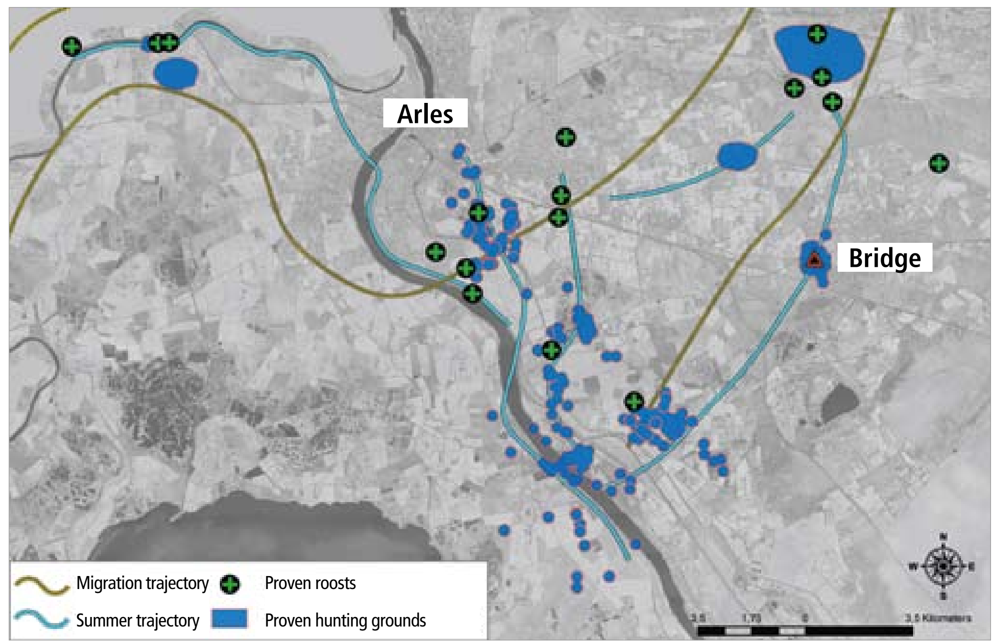


Representation of a Greater Horseshoe bat flight path identified by telemetry. Blue dotted line, the shortest route from the roost to the hunting site : in red, the route proven during the telemetry. The crossing area of the highway (shaded area) was not been specified in the telemetry session.

The detour is 8 km instead of 5 km direct flight. It seems that the Greater Horseshoe Bat prefers to take a longer but more linear route than the direct path which is without vertical structures. The area of road crossing was not, however, highlighting accurately during telemetry.

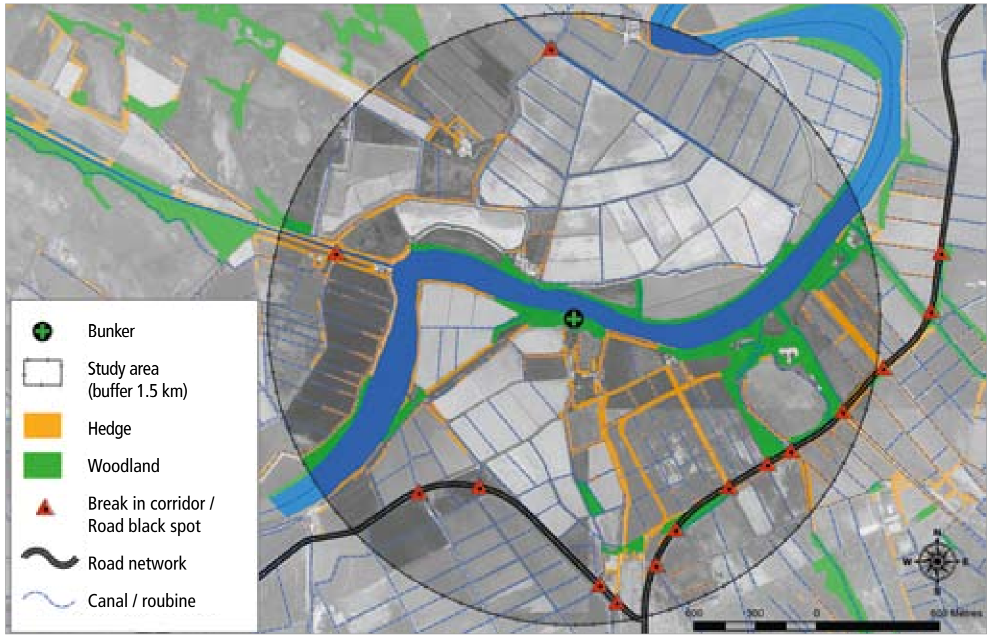
The following map summarizes the main transit routes south of Arles. The migratory routes have been established to represent the interaction between large geographic units such as Camargue and the Alpilles. Transit routes are the result of specific or occasional sightings during movements of bats in the summer. They remain sketchy but identify issues such as the southwest sector of Saint-Martin-de-Crau, the area which is the business hub of the town, in relation to crossing it, and even hunting in rare woodland and wetland areas around the RN113.

Some principal flight routes are valuable results and have a particular importance, like the passage along the Rhone south of Arles, which is the exact point where a crossing of the Grand Rhone is projected in relation to the future A54. Over and above the destruction of proved hunting areas, this new highway (dual carraigeway) will integrate, on its completion, the largest possible number of underpasses and overpasses for bats in order to minimize road deaths. The structure intended for the crossing of the Grand Rhone is a viaduct which will be 1.6 km long, between the embankments of the river. The landscaping around this project will guide wildlife, and notably bats, to pass under the viaduct without risk of being at the height of vehicles, by way of linear structures of vegetation (continuous line of vegetation with height reduced in the vicinity of the structure).



Axes of movement of the Greater Horseshoe Bat and Geoffroy's bat deducted from the results of telemetry, for the summer period, migration and the hunting grounds.

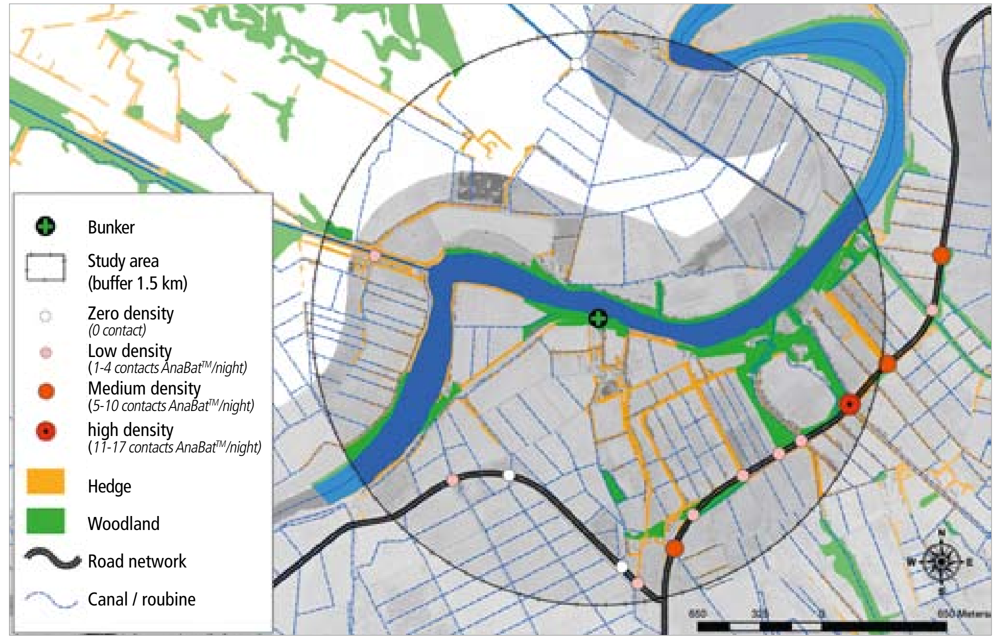
Detailed mapping of habitats favourable to transit around roosts allowed localisation of all potential points of conflict between Greater Horseshoe Bats and Geoffroy's Bats and roadways. This work involved preparing the next phase of expertise of these road black spots.



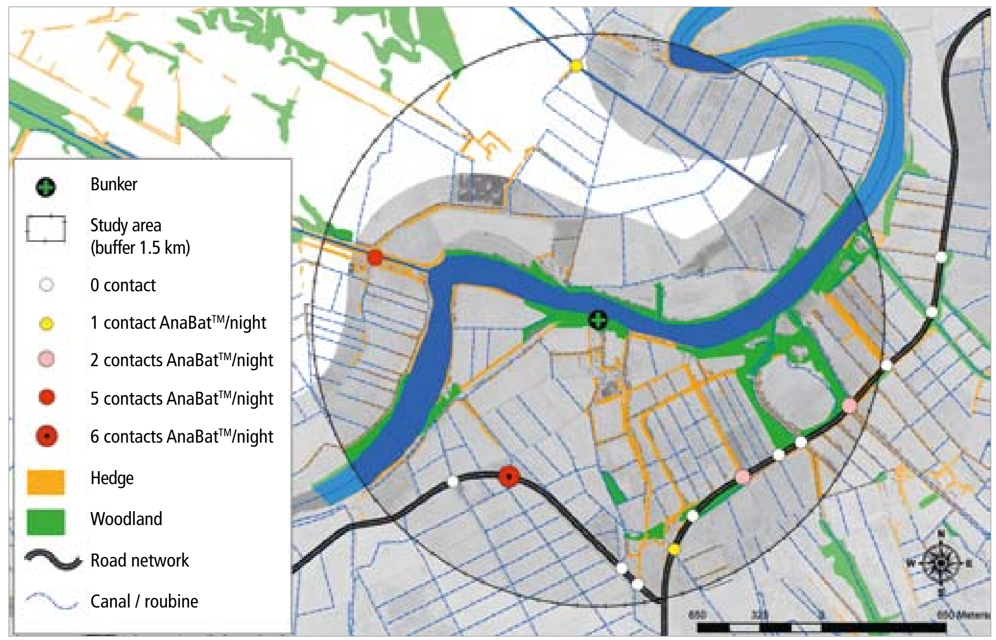
Mapping roadways (networks of hedges, river, canal and roubine) and potential bat crossing areas (red triangles) around a breeding colony (bunker) carried out under the LIFE+ Chiro Med program in 2011.

The acoustic expertise of potential black spots : The evaluation and validation of potential crossing points and improvements in their localisation were made by acoustic expertise during the night by using **AnaBat™** placed along the roadways. The readings (129 AnaBat™ used) were carried out on 42 nights spread over all potential black spots from May to August to address the seasonal variability of flight routes used. This indispensable phase provided a detailed assessment of the use of space around the roosts by the bats targeted by the program.

Behavioural observations of bats were conducted at the proven black spots. Imaging techniques (*see* technical guide No. 6 "Imaging Techniques in the service of conservation" enabled these behavioural observations.



Density of the passage of Greater Horseshoe bats over highways around a breeding roost and localisation of the point with the highest density of passage (red spot / black dot) which will be equipped with a experimental system.



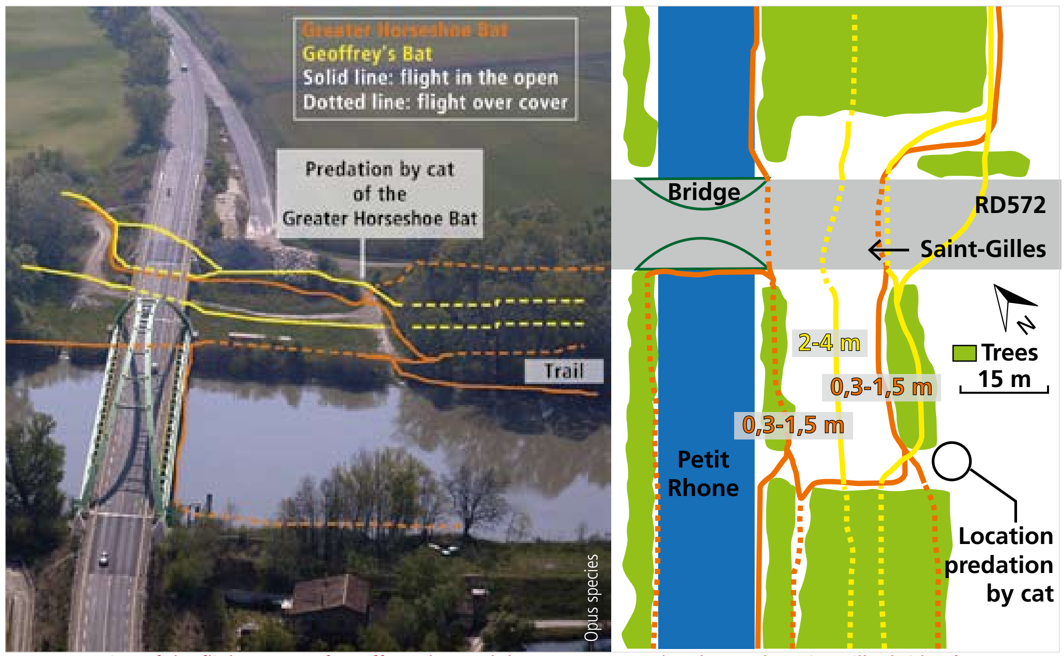
Density of the passage of Murines type Frequency Modulated (FM steep high frequency) over highways around a breeding roost and localisation of the point with the highest density of passage (red spot / black dot).

Description of the behaviour of the two target species

Comparison of flight behaviour of the two species

According to the observations made in 2010 (A6) near the Saint-Gilles bridge (RD572) **Geoffroy's Bat** favoured flight in the inner part of the dense riparian vegetation. A large number of contacts were recorded there at the exit of the dense edge between 2 and 4 m high, where vegetation is interrupted by a bridge.
Between the riparian vegetation and the bridge, two types of behaviour were observed in equal proportions. At the exit of the dense vegetation, some animals move towards the shrubs and fly within 50 cm of the vegetation, while others cross the 50 m of open space between the two exposed riparian woods at between 2 and 4 m. In both cases, most pass just below the apron. Some individuals still pass over the road. Furthermore, individuals were seen crossing roadways diagonally, or even flying over the surface parallel to its axis generally more than 4 m in height. These behaviours seem to show some tranquillity or unawareness by the Geoffroy's Bats vis-a-vis the traffic on this road which was not continuous at the time of the observations.

It therefore appears that the Geoffrey's Bat prefers to travel over dense wooded areas, not that this prevents them crossing open spaces at several meters of altitude unlike the Greater Horseshoe Bat which has a much more demanding mode of travel. In other conditions, outside the roost and in open in ploughed fields, this kind of Murine can fly at 20 cm over the soil over several tens of meters before going into woods (obs. GCP Var).



Representation of the flight routes of Geoffroy's bat and the Greater Horseshoe bat at the Saint-Gilles bridge (RN572, Bouches-du-Rhône) with some indications of the flying height.

Indeed, on the same site, **Greater Horseshoe Bats** travel along the riparian woodland, along the Petit Rhone or the embankment and fly close to the ground (most often between 0.3 and 1.5 m in height) a couple of dozen or so centimetres from the vegetation. They also follow the path through the riparian woodland. Then they follow a flight path under the road edge abutment or towards the embankment of the Petit Rhone. This low flying height makes it susceptible to predation by cats as was discovered on this site at a point where Greater Horseshoe Bats were accustomed to flying 30 cm from the ground. In this context, the Greater Horseshoe Bat clearly appears to avoid dense environments in favour of sparse areas or borders.

Behaviour in the presence of a moving light source

The results of nocturnal observations with the thermal camera suggest that Greater Horseshoe bats seek to avoid powerful light sources, possibly associated with movement.

Indeed, U-turns have been observed after the approach of a vehicle (headlights on).

Another observation was made on the bridge of Saint-Gilles which crosses the Petit Rhone and where Greater Horseshoe bats pass daily to go to the other shore. When an illuminated barge passes under the bridge the Greater Horseshoe bats change their trajectories and turn around. Travel from one bank to another resumes once the light source is further away.

IN BRIEF

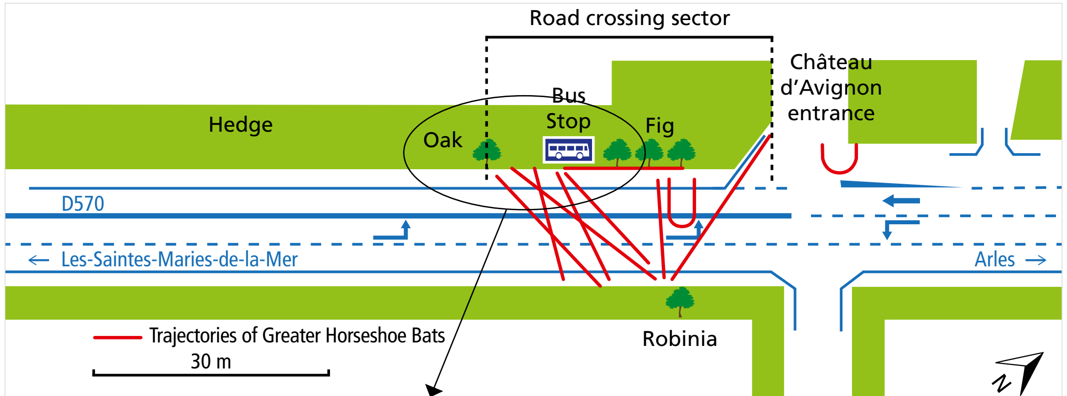
The Geoffroy's Bat

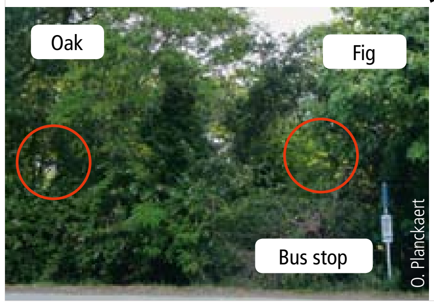
The species prefers to frequent **dense woods** such as the riparian woodland of the Rhone for hunting and when in transit (report A5 "Telemetry"). However it easily crosses **open areas at medium altitude** (2-4 m high in most cases).

Therefore, Geoffroy 's Bat **seems little affected by road deaths** (flying over the area at risk of high collision, less corpses found). They also certainly use objects like bridges over roads, even if they where not intended for them.

Use of wooded gaps

In 2011, the research into road crossing zones by Greater Horseshoe Bats led to the determination that these sectors are generally characterized by the presence of a hedge cut perpendicularly by the road surface. The presence of pastures by the roadside seems also to affect the choice by individuals who cross roads in the Camargue. The Greater Horseshoe Bat uses mainly hedges or borders to arrive at the roads that need to be crossed. Observations made at these crossing areas showed that sectors with longitudinal hedges are widely used by Greater Horseshoe Bats and they prefer to cross where there are wooded gaps in hedges (opening between two bushes or at the entrance to a field), thus avoiding the passage above the tree tops.





The trajectories of Greater Horseshoe bats (red lines) and the two gaps (red circles in the picture) widely used by the bats to cross the hedge bordering the RD570 (towards the chateau of Avignon, Saintes-Maries-de-la-Mer).

These first elements in the choice of road crossing zone by the Greater Horseshoe Bat will enable, in the future, better targeting of the sensitive areas where road improvements can be proposed but also the adaptation of those road improvements to be as effective as possible. However, these results can not be systematically extrapolated to areas other than the Camargue, because of the local landscape context and topography of the crossing zones (no underpasses possible in the Camargue, although they are preferred by Greater Horseshoe Bats).

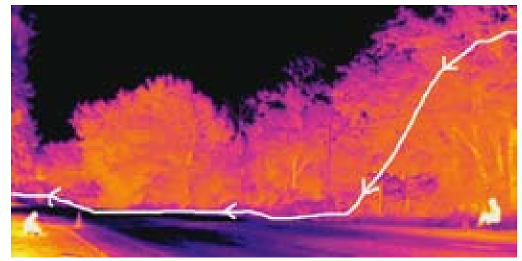
The landscaping of roads and their maintenance is a key element in the transit of Greater Horseshoe Bats. Inadequate management of road borders and brutal modification of the landscape in a flight path may cause behavioural changes and mortality depending on the context.

IN BRIEF

The Greater Horseshoe Bat

Greater Horseshoe bats **fly along vegetation** and **shave close to the ground** in the absence of vertical landscape structure by taking the shortest path to get back to vegetation. The flying height of an individual in the middle of a road depends on the height of its flight when it leaves the hedge for the road.

In crossing a road, these bats find themselves at the height of cars in most cases. They are then **directly affected by road deaths on roads** with a high volume traffic (mortality proved on the RN113) as on narrow roads with less dense traffic but which travels at high speed (mortality proven on the RD179, south of Saint-Gilles).



Trajectory of a Greater Horseshoe bat when crossing a road, observed with the thermal camera. © T. Stoecklé

EXPERIMENTAL DEVICES TO HELP WITH ROAD CROSSING

In order to strengthen and improve the conservation of the Greater Horseshoe Bat and Geoffroy's Bat, the LIFE+ Chiro Med program has fixed, among its main objectives, to install and and test two types of experimental system to help with road crossing at identified black spots :

- Audible warning devices at two sites on roads near the largest colony of both species in the Camargue (about 1,200 individuals).
- A bat corridor to improve the permeability between the north and south of the RN113, the future A54.

Establishment of audible warning devices

The aim of this work is to test the effectiveness of road surfaces as warning sounds to alert bats and particularly the Greater Horseshoe Bat to the arrival of a vehicle in order to limit mortality on the roads as they cross them. The goal is not to frighten bats or prevent them from crossing the road, but to inform them of approaching danger. This device is based on the learning capacity of bats by associating a sound stimulus with a danger in order to trigger avoidance behaviour, especially in the young.
The sites selected to test these devices are the crossing areas which have been proved as areas of high risk of death for Greater Horseshoe Bats. They are situated on sections of road where surface repairs were planned by the General Council of Bouches -du- Rhône in 2012 (RD570 and RD572).

Stakeholders to solicit

Before embarking on the creation of a road crossing device for wildlife which modifies the structure of a road surface, it is essential to establish a close partnership with the manager of the road and to inform residents.
The General Council of Bouches-du-Rhône, which manages the two roads targeted for experimentation, is very committed to this project. Indeed, a long-term program to reduce impact on the local environment has been engaged in. As such, the approach of the LIFE+ Chiro Med on the issue of "roads and bats" and more generally the approach of the Bat Group of Provence on this subject are fully consistent with the objectives of the community. The involvement of GC13 in this area was awarded the prize "Infrastructures for Mobility and Biodiversity" from the IDRRIM (Institute Of Roads, Streets and Infrastructure for Mobility) in 2013.

Device selection

The main constraint in the Camargue is the topography (elevation between -1.50 m and 4 m relative to sea level) and the lack of underpasses, except rare hydraulic passages of small dimensions. In this context, the crossing of roads by bats is systematically done over the top of roadways.

Envisaged originally, prototype hanging nets, overhead wires and crossing gates for man / bat were abandoned after discussions with the General Council road services. The principle of the project was not in question but these devices seemed inadequate because of the length of the bat crossing points, the development time for such devices, the strong wind in these places, and their visual impact on an area which is particularly touristic. A device which startles by light or ultrasound was imagined in relation to scientific studies carried out in Europe. But the solution of startling does not seem appropriate in this case and might cause displacement of the flight path to cross the road at another place and possibly increase the risk of collision. In addition, this requires an expensive investment and access to electricity, not to mention the high risk of theft of the devices, as has been experienced in the UK with lit bollards.

It was decided to work on simple and targeted audible systems for the Greater Horseshoe Bat, the species mainly present at the road black spots identified. Geoffroy's Bat is not affected or very little affected. The development of a crossing point safe for bats by installing an audible warning is an experimental project destined to be permanent.

Constraints
The choice of a permanent audible warning device must take into account constraints connected to the comfort and safety of road users and residents while providing optimal functionality with respect to bats.

Several devices have been proposed :

Device type	Normal use	Advantages	Disadvantages
Rumble strips	Placed as a coating to the road surface. Warns drivers of an imminent hazard(roundabout tight turn, end of straight line).	- Generates an audible warning for a variable amount of time defined by the length and the space between the bands. - Low Cost.	- Can be used in an area without apparent danger to drivers (incredibility of the system). - Sound annoyance for motorists and residents.
Vibrator	Raised pattern defining the edge of the roadway. Prevents the risk of falling asleep whilst driving on the highway.	- Generates a powerful warning sound and causes shaking of the vehicle and mechanical noises that produce ultrasound.	Cannot be installed across the road width wise or in large areas on the road surface.
Air flange	Traffic counter.	- Generates an audible warning of a snapping sound, usually repeated by the passage of two axles. - No special effect on motorists. - Low Cost.	Sound annoyance for motorists and residents. Potential for breakdown and control necessary.

Device type	Normal use	Advantages	Disadvantages
Granular coating	Type of road surface standard on strips of road.	- Generates an audible warning continuous and not jerky. - No special effect on motorists. - Low Cost.	Sound annoyance reduced unless the size of the grains is very large.
Granular coating specifically noisy	Type of road surface standard on strips of road.	- No annoyance for motorists, or for local residents. - Can be specific to a given range of ultrasound (not audible to humans).	Need to redo the road near the device by resurfacing and finishing after installation of the standard coating.
Speed limit	Role of safety in case of danger to motorists or pedestrians.	- It has been reported in literature that below a speed of 50 km/h, the risk collision with a vehicle was low to very low. - Very low cost.	- Ineffective if not respected. - Can be installed only if the crossing of bats is a danger or disruption to drivers (*eg.* reflex avoidance, swerving, sudden braking, inattention, etc.).
Panels "Bats crossing"	- Notifies drivers to a potential danger. - Notifies of the risk of collision with bats. - Adaptation of driving and alertness	- Changing the vigilance of the driver to face a potential danger. - Inform citizens of problems caused by the automobile on a specific fauna. - Very low cost.	Does not cause a systematic reduction in speed. Lack of visibility of actual danger. Small size and stealth of the animal. No warning signal of an approaching danger to bats. Efficiency unknown despite the existence of these panels in some countries.

Principle of operation of the warning equipment selected
The device selected targets Greater Horseshoe Bats, highly exposed to the risks of collision with vehicles on the road and, to whom the consequences of increased mortality on local populations are dramatic because of its biological and demographic characteristics.
The method of selecting a device specific to any other species of bat could be transposable.

Sensitivity of Greater Horseshoe Bats to low frequencies
The hearing of the Greater Horseshoe Bat is sensitive to different frequency ranges and more sensitive than that of Man in the order of -5 dB -SPL for the frequencies to which it is most sensitive. **Very sensitive between 12 and 20 kHz**, then at around 60 and 83 kHz, his hearing is a little less sensitive between 20 and 35 kHz, and very little at other frequencies. Low frequencies are used by the species to communicate (social calls).
Sound recordings were made with a time expanding ultrasonic detector (Pettersson D240x) and a digital recorder (Zoom H2) in a Greater Horseshoe Bat roost in the Camargue to evaluate the transmission frequencies and also the use of low frequency by the species (10-35 kHz). These sounds were analyzed with the software Batsound. The analysis showed that **the most powerful Greater Horseshoe Bat social calls are issued between 15 and 22 kHz**.
It has been deduced that the species is sensitive to these frequencies and that it was possible to use them in warning sounds.

EXPERIMENTAL DEVICES TO HELP WITH ROAD CROSSING

The road surface to select is the one that generates the most powerful sounds at these frequencies during the passage of a vehicle (*see report* "road surfaces").

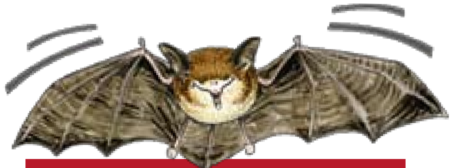
Choice of road surface
The contact tyre/road surface generates a noise when a vehicle moves. The audible level of this noise varies depending on the type of surface coating and the speed of movement of the vehicle.
The Laboratory of Civil Engineering of Strasbourg (CETE East) provided recordings of the standard sound made by 6 types of road surface : ES46, BBS-G010, ECF-06, BBTM010 and BBT-M06-Class 2 (Class 2 = class of the resistance of the mineral material = good resistance corresponding to silico- limestone or basalt).
The maximum sound made by the passage of a single vehicle was measured using the Batsound software in the range of frequencies 15,000 to 22,000Hz.
The sound maximums recorded by the Bridge and Road Service to control noise nuisance to road users and residents are measured for frequencies between 100 and 5,000 Hz (audible and annoying to humans, human hearing is between 20 Hz and 16-18,000 Hz ; 20,000 Hz for children and adolescents). The noisiest coatings at these frequencies are not necessarily the noisiest between 15 and 22 kHz (above the audible limit within the range of man).

Of the 6 road surfaces tested in this study, the BBT-M010 is the surface commonly used on roadways in the Bouches-du-Rhône. It generates the lowest maximum sound level between 15 and 22 kHz. The ECF-06 generates the strongest sound from the passage of light vehicles, in the range of auditory sensitivity of Greater Horseshoe Bat (15-22 kHz) just in front of the BBT-M06-Class 2 (*see report* "road surfaces").

The ECF-06 (cold-cast coated) did not fall within the annual budget framework of the Bouches-du-Rhône General Council. The work has been carried out using **the coating BBT-M06-Class 2**. Forthwith in this guide, this coating is called special coating. It would however have been preferable to use the ECF-06 for this type of device .

Physical constraints
The configuration of the device should warn bats of an approaching vehicle, at a place where they cross the road, and give them time to respond despite the speed of the vehicle (to turn, raise the height of flight, etc.).
These elements will help define the length of the coated strips, which are especially noisy at high frequency, and the distance necessary between these strips and the crossing area for the device to be operational.
In relation to the two crossing points selected for this experiment, "crossing zones"have been identified. They correspond to the areas where the Greater Horseshoe Bat cross in larger concentration. On the RD570, this zone extends 37 m on the RD572, it extends over 58 m.
The average speed of vehicles on the experimental section of the RD570 is around 100 km/h. At this speed, a vehicle takes 0.72 seconds to travel along a strip of 20 m. The sound generated by the friction of the wheels of the vehicle on the special coating therefore lasts 0.72 s. The bats are able to discriminate between two closely spaced sounds. They receive the echoes of their ultrasonic pulse which is emitted at a very high recurrence, sometimes 40 to 50 pulses of ultrasound per seconds before capturing prey. They therefore have a very powerful auditory discrimination around 0.02 s between two sounds and are therefore sensitive to a signal of 0.72 s. Man has a discrimination capacity five to ten times weaker.

In addition, if a bat is 40 m from the sound source it receives, it reaches him in 0.12 s whilst the vehicle that has generated the sound will reach his position in 1.44 s. The maximum speed observed in this species is 8.3 m/s or 30 km/h. So it takes about 2.2 to 3.2 s to cross an 18 m road surface. The bat has, in theory, enough time, 1.32 s (1.44 to 0.12), to respond to the sound stimulus and adapt its flight behaviour to avoid collision knowing that it will still be above the road when the vehicle enters the point of potential collision.



OBSERVATION

Sound loses power while moving through the air. Conventionally, it loses about 6-dB-SPL at each doubling of the distance of propagation. Bass sounds (low frequencies) propagate further than sharp ones (high frequencies).
For reference, a 30 kHz sound of moderate intensity spreads for about thirty meters.
The sounds generated by vehicles on the road surface which Greater Horseshoe bats are sensitive to are bass (15-25kHz), and will carry more than 40 meters for the hearing of Man and even more for a Greater Horseshoe bat which has more effective hearing (hearing capacity increased to -5 dB-SPL).

Case of the RD570

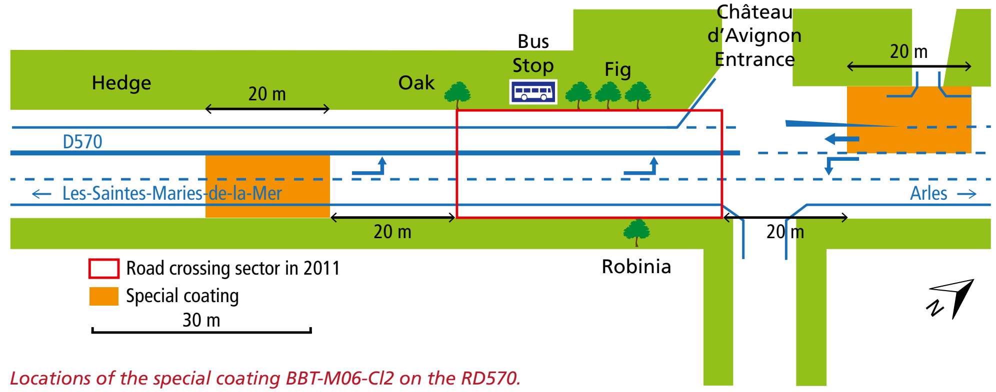
The RD570 presents a major challenge for the Greater Horseshoe Bat at the entrance of the Chateau of Avignon (Saintes-Maries-de-la-Mer, Bouches-du-Rhône).

In summer, this species crosses the RD570 daily. Crossings are concentrated over an area of 37 m in length (minimum of 17 contacts per night).

On crossing, Greater Horseshoe bats fly between 0.5 m and 1.5 m above the road surface and it takes about 2.2 to 3.2 seconds to cross the three lanes. they take a considerable risk, they will cross the road twice a day at least, from May to August and furthermore, an individual passes over many other roads in its 40 km daily flight. They are highly exposed to vehicles travelling at high speed (over of 50 km/h).

Observed track of a Greater Horseshoe Bat. © O. Planckaert

The device placed on the RD570 in November 2012 consists of two bands of 20 m of special coating BBT-M06-Cl2 located 20 m before the start of the crossing area of the Greater Horseshoe Bats in each direction.



Locations of the special coating BBT-M06-Cl2 on the RD570.

Behavioural observations on the RD570 were conducted in 2013 using the same methodology as in 2011 when the initial state was observed. The animals thus had a spring and early summer to use the device. The identified crossing area is more spread out than before the laying of the strips of BBT-M06-Class2. However, it is difficult to attribute this modification to the presence of the device, or an improvement in observations, or another external factor. Indeed, despite the loyalty of bats to their roosts and their axes of movement, annual variations in behaviour are not excluded.

The sonic bands had **no significant effect on the flying height** of the Greater Horseshoe Bats. However, **as before the laying of the bands, the flying height of a Greater Horseshoe Bat above the road surface depends on its flying height when it reaches the road.**

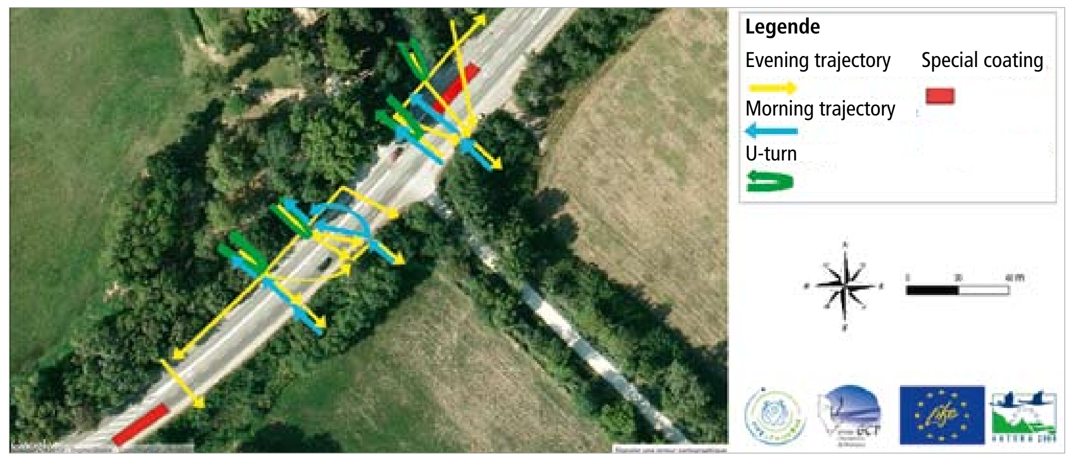


Diagram of the different flight paths of large horseshoe bats in 2013. Trajectories on the sonic band to the north had not been observed in 2011. The flight routes in 2011 were focused on the central part. © Google Earth

The trajectories of the Greater Horseshoe Bats in the morning, when returning to the roost, are much more direct than the evening. In parallel, the number of vehicles on this stretch in the morning (average of 26 vehicles in 20 minutes during the time the animals pass) is significantly less than the number of vehicles travelling in the evening (on average 125 vehicles in 20 minutes). The risk of motor vehicle collision is more significant in the evening.

As a guideline, the distribution of road crossing behaviour by Greater Horseshoe bats at all crossing areas identified in 2011 showed that over 83% of individuals observed crossed directly over the road. Only 3% made a U-turn at the start or middle of the road (*see* Figure 1).

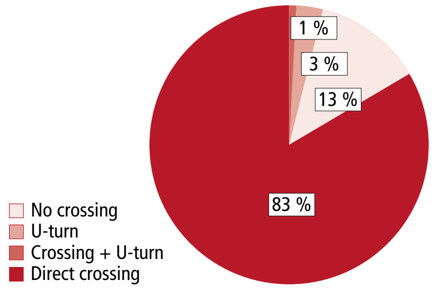


Figure 1 : *Behaviour of Greater Horseshoe bat on crossing the RD570 for all visual contacts (N=257) around the colonies of the Camargue (Summer 2011).*

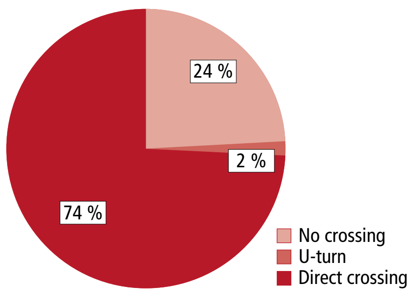


Figure 2 : *Behaviour of Greater Horseshoe bat on crossing the RD570 for all visual contacts (N=100) in the absence of sonic bands (summer 2011).*

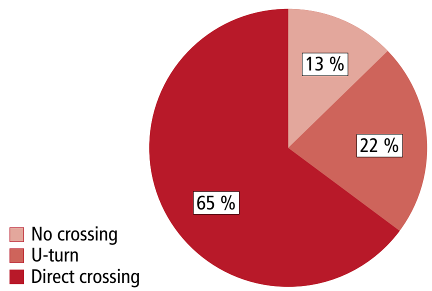


Figure 3 : *Behaviour of Greater Horseshoe bat on crossing the RD570 for all visual contacts (N=94) in the presence of sonic bands (summer 2013).*

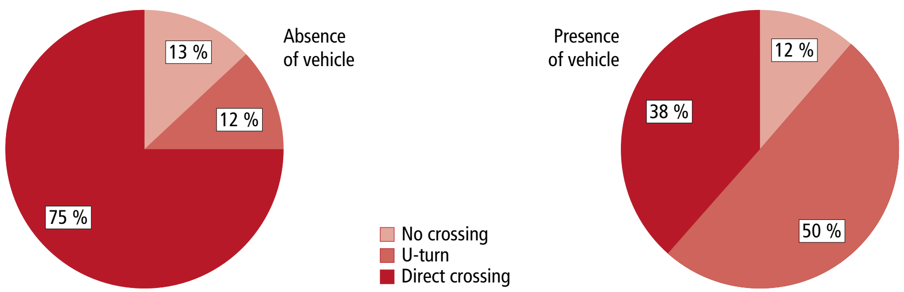


Figure 4 : *Behaviour of Greater Horseshoe bat on crossing the RD570 in the absence (N=68) or in the presence (N=26) of a vehicle in the crossing zone equipped with a audible warning device (summer 2013).*

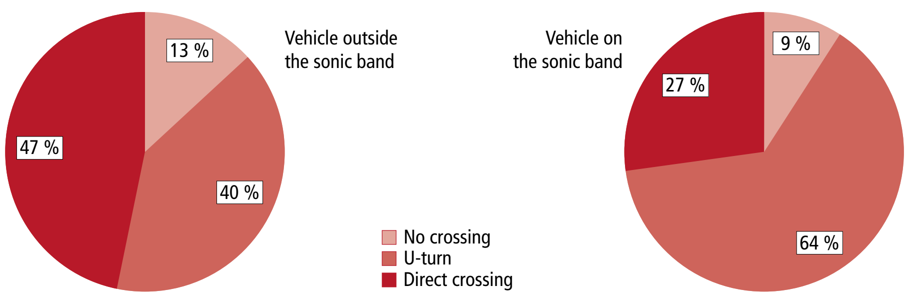


Figure 5 : *Comparison of the crossing behaviour of Greater Horseshoe bats when the vehicle is outside the sonic band (N=15) or on the sonic band (N= 11) on the RD570 with a audible warning device (summer 2013).*

EXPERIMENTAL DEVICES TO HELP WITH ROAD CROSSING

The comparison of the behavioural observations on the RD570, at the crossing zone targeted for testing the warning device for Greater Horseshoe Bats gave the following results :

- Greater Horseshoe Bats seem generally more reluctant to cross the road than before the laying of the device : 74% (*see* Figure 2) of individuals observed during the preliminary study crossed the road directly against 65% in the presence of the device (*see* Figure 3). In addition 2% of individuals observed in the preliminary study performed a U-turn compared to 23% in the presence of the device.
- In 2013, observations showed that the crossing behaviour of Greater Horseshoe Bats differed significantly according to the absence or presence of a vehicle (*see* Figure 4).
- Differences were also found between the behaviour observed when a vehicle was on the special coating or when it was on the classical bitumen : Greater Horseshoe Bats made more U-turns when a vehicle was on the sonic band at the time they arrived at the road (75%) than when a vehicle was on conventional bitumen (38%). However, these results are not significant. Similarly 47% individuals crossed the road directly when a vehicle was outside of the sonic band against 27% when a vehicle was on the sonic band (*see* Figure 5).

IN BRIEF

These observations suggest that Greater Horseshoe bats have significantly altered their flight behaviour to cross the RD570 at the audible warning device. Although there is no evidence that they associate the noise generated by sonic band with the presence of a hazard (vehicle), it seems that they have an increased awareness of the approach of a vehicle when coming to a road and have developed avoidance behaviours (compared to 2011). Recall that the animals had only few months to get used to the area.

This device seems to work but needs to be improved. Its assessment is to be continued on other sites to confirm the effect of behavioural adaptation by Greater Horseshoe bats.

Recommendations and perspectives

This device has given successful results in the Camargue. Improvements can however be made at several levels.

- It is possible that the change in sound intensity at the transition point between the two types of coating (beginning and end of the band) is greater that the sound signal generated by the tyre rolling on the coating itself. Thus, in order to increase the number of transitions between special coating / classic coating and to share the sound signals over the whole of the crossing area identified, sonic bands could be shorter (10-15 m), and closer to each other (15-20 m) and in a greater number (to cover the length of the crossing zone identified).
- The use of two types of coating that generate a more contrasting sound when a vehicle passes, so that the sound level difference is greater. The use of the ECF-06 coating is recommended.
- The installation of bands in the crossing zone of the Greater Horseshoe bats, not only before it.

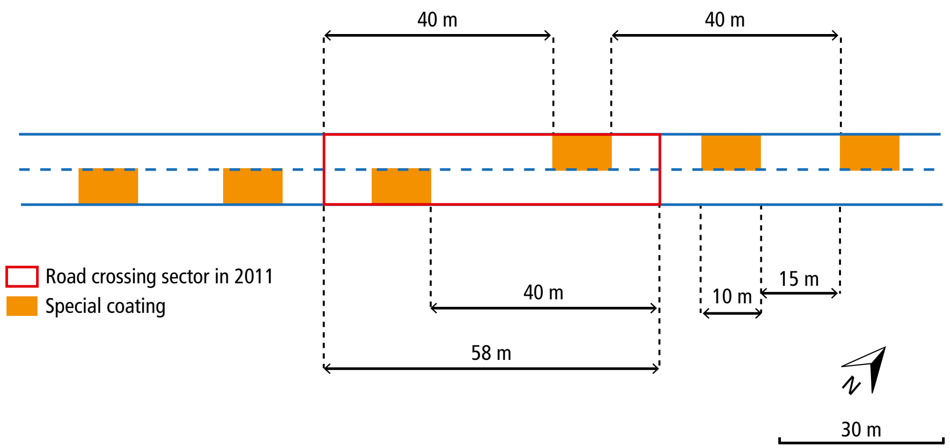
Case of the RD572


E. Cosson

The RD572 The RD572 at the Saliers crossroads (Arles, Bouches-du-Rhône) is a sector that presents a great challenge for the Greater Horseshoe bat.
This crossing zone was spotted during telemetry monitoring and was subsequently pinpointed using acoustic expertise and night observations with a thermal camera at potential black spots (map p18).

The crossing of this road by the Greater Horseshoe bat is focused in a zone 58 m long over which individuals are exposed to a high number of vehicles (annual average daily traffic of 6,700 vehicles).

To go further in the experiment, the LIFE+ Chiro Med program took advantage of a delay in the installation of the second device to quickly implement two of the improvements proposed following the observations on the RD570.
Thus, to increase the number of transitions between the two types of coating, this device consists of 3 bands of BBT-M06-Cl2 each 10 m in length and spaced 15 m apart. So that the sounds generated by the device are perceived even by a bat approaching the road at the end of the crossing zone (length = 58 m), the last band is located 40 m from the end of the zone as shown in the following diagram :



Location of the special coating BBT-M06-Cl2 on the RD572.

This second device will be put in place at the end of the LIFE+ Chiro Med and was therefore unable to be subject to observations within the framework of the program. These observations may be made later in order to assess the effect of the devices in the medium-term.

Cost of the devices

A refurbishment of the surface of a main road (2x1 lane) costs approximately € 70,000 per kilometre. The estimated cost of laying bands of the noisy special coating to warn bats is only different if the operation is conducted in a place where the road surface is already in place or if it is integrated in a program to renovate a portion of the road network. The high cost of this work is related to the surface laying machinery. If this is done during a renovation in progress, only the planning, the purchase and laying of the specific mix needs to be considered (*see* boxes).

On the RD570, the laying of the specific coating was integrated into modification work to the road surface. **The cost of this device is estimated at € 1,700 for 2 bands of 20 m long and 8.5 m wide** (road deceleration=340 m²).

This work was funded by the General Council of Bouches-du-Rhône, manager of this development and technical partner of the LIFE+ Chiro Med program.

CG13

On the RD572, laying bands of BBT-M06-Cl2 was not completed during repair work on the road surface . This involved bringing machinery to the site to remove the asphalt and replace the current coating with the special coating .

This increased the cost of the installation of the device to approximately **€ 5,000 for 6 strips of 10 m long and 3 m wide (180 m²)**. Construction time was a maximum of half a day.

This work was funded by the General Council of Bouches-du-Rhône , manager of this development and technical partner of the LIFE+ Chiro Med program.


E. Cosson

Marking the road to indicate the zones of special coating to the works manager on the RD572.

Geoffroy's bat

Assessment and prospects for improvement

The use of audible warning devices built into the road surface to alert bats to an approaching vehicle is experimental. Bats are sensitive to sound stimuli. The singularity of the device tested here is that the warning sound is generated by the approach of a hazard (vehicle). It therefore appealed to the learning ability of bats.

This device was developed to target the Greater Horseshoe Bat given its high risk of mortality on the roads. However, it may relate to other species whose hearing sensitivity range is similar to that of Greater Horseshoe Bat (high sensitivity between 12 and 20 kHz). To target other species, we must have their behavioural audiograms and adapt the type of coating according to the frequency range in which the level must be generated. The especially noisy coating must also be chosen depending on the type of coating commonly used on the road by the device concerned.

The methodology implemented has shown its effectiveness but we still have to optimize to improve results.

Note, however, this device is probably not suitable for high-speed roads, broad, highly populated, and whose speed limit is 110 or 130 km/h, because bats would not have time to react to the sound stimulus or manage the abundance of vehicles.

At 110 km/h , a vehicle takes 1.31 s (seconds) to travel 40 m, whereas the generated signal takes 0.12 s. Bats therefore have 1.19 s (=1.31 to 0.12), to react. However, over 40 m in a noisy environment, the sound becomes less noticeable and another vehicle must not arrive in the other direction at the same time or the potential for avoidance is reduced. If a bat crossed the road 10 m from the sound source, it would have 0.30 s (0.33 to 0.03) to react and would appear to already be compromised if only by the aspiration created by the vehicle.
At 130 km/h, if the bat approaches the road 10 m from the audible warning device it will only have 0.25 s to react before the car hits it.
In such situations, the chances of survival of a crossing Greater Horseshoe Bat seem to be almost zero. We must therefore work on other options for these busy roads (*see* further down the part covering the establishment of an experimental corridor).

Beyond all these considerations about the perception of sounds, such a device will probably not be effective on roads with dense and continuous traffic where animals certainly have a clear perception of danger but are forced to pass or divert which reduces their habitat (fragmentation). Studies on road deaths of the Greater Horseshoe Bat seem to show this clearly. The use of audible warning bands should be used primarily on roads with non continuous traffic and with a speed limit of less than 100 km/h which means there are many areas where this can be achieved.

Nevertheless, an audible warning device in a specific motorway context remains to be studied and evaluated.

Establishment of an experimental corridor on the RN113

The experimental device is aimed at **facilitating the crossing of the RN113** by bats, by establishing a continuum of flight navigation between the north and south of the road by using a **corridor for bats**. Due to the flatness of the Crau plain, there are indeed very few underpasses below the RN113, and the A54, which has only three wildlife crossing underpasses which are unsuitable (too low and some are flooded).
The objective is to improve and test a pass over the motorway by redeveloping an existing bridge already frequented by both species targeted by the LIFE+ program. The principle of operation is based on the learning ability of bats in the face of a new landscape. Bats are extremely sensitive to changes in their environment. If an item is removed (a tree cut down for example), or if an item appears (installation of a camera as part of making a film for LIFE+ CHIRO MED) on their axis of movement, they change their flight route. This observation was also verified where a capture net was used : if a net is placed over several consecutive nights at the same place, bats caught the first night will avoid the area over subsequent nights, even if the net is removed. However, they resume their flight habits after a few days.
By incorporating a new element (artificial corridor) into their environment, their curiosity is needed. They then require time to analyze this new element, realise that the passage is secure, protected from the wind, light and noise. The aim is that they have sufficient confidence in the corridor to change their flight paths and use the passage.

The development of this experimental device is integrated into several areas of recovery of ecological continuities, in a comprehensive use of the ecological functionality of the territory, in the National Plan of Action for bats (national and regional implications), in remedial measures following the LOTI* report (national), in the approach used by the Green and Blue Networks (regional and local), in promoting innovative measures for the new A54 which must be added to existing roads over 26 km of core hunting areas of the species, in its environmental redevelopment of existing sections (Package Green Motorway* and Program of Modernization of Infastructure*) and in the application of DOCOB Natura 2000* (regional and local).

Stakeholders to solicit

Before undertaking the realization of a road crossing device at a public construction, it is necessary to contact :
- the manager of the road to be crossed (Interdepartmental Directorate of Roads - DIR or Council General or the Society Concessionaire for motorways or Réseau Ferré de France - RFF),
- the manager of the road bridge,
- local elected officials whose citizens use these routes.

The DIR, manager of the road bridge and the road to be crossed in the area of implantation of the experimental device, has invested heavily in the project.

Choice of experimental site

Site constraints
A survey of technical constraints and security is to be made prior to any installation.

- Do not use a site that suffers from problems (overall fragility of structure and cracks), which may cause stability issues.

- Identify operational constraints that apply to the site :

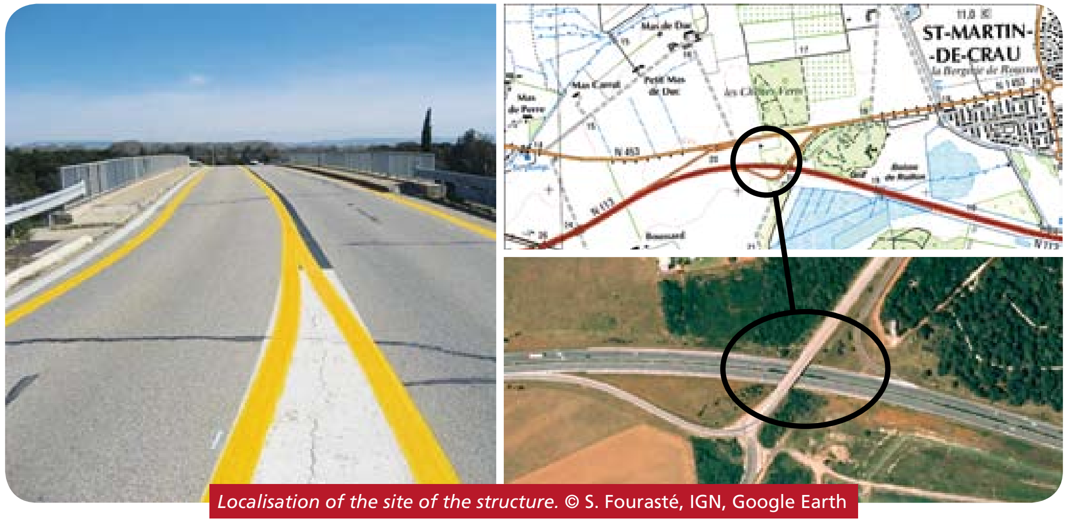
  - *road bridge* : plan that the width of the device may require modification of the width of the road surface or the number of lanes. Certain operating constraints of the road may limit the possibility of modification of the transverse profile (*eg*. on a planned route for the passage of abnormal loads),
  - *Road to be crossed* : the development work on banks, therefore above the road to be crossed should not generate disorder, mess or lack of security on the road. The project must comply with the constraints of road work operations, including the organization and planning of the work.

Note in the particular case where there is a railway line present :

1. the third party must seek advice from the SNCF Infra (which ensures the management, operation and maintenance of the rail network on behalf of RFF) for interventions that have an impact on rail traffic (deposit of overhead lines, slowdown interruption of movement) and to pre-register work in relation to the installation of a device with RFF services, this can cause a delay of up to 3 years,
2. RFF and SNCF Infra then propose, on this basis, time spans of possible interventions in relation to work already planned and the workload of the SNCF. If the realization of these operations requires access to public rail network, the third party is required to notify the SNCF Infra of the intervention at the said area, in accordance with an advance notice of 6 months, so that the SNCF Infra can accompany the third party with support agents,
3. for interventions that may have an impact on rail traffic (deposit of overhead lines, slowdown interruption of movement) a financial compensation may be requested,
4. The third party is required to prepare under the regulations in force, any measure of protection and prevention which is needed, including the following documents :
   - rail safety special notices,
   - prevention plans,
   - documents prepared under the SPS coordinator (safety and prevention coordinator).

Description of the experimental site
The development of this experimental corridor for bats was carried out on an existing structure close to known hunting sites of the Greater Horseshoe Bat and Geoffroy's Bat, determined in 2009 by telemetry. It is located less than 1.5 miles north of a sector frequented by many species of bats, Leuze wood (Saint-Martin-de-Crau, Bouches-du-Rhône), 600 m from a wooded area used by the Greater Horseshoe Bat in a business zone in the area of Saint-Martin-de-Crau east of lower Raillon (pond) and close to the south of the wooded area "les chênes verts" used by Geoffroy's Bat for hunting.
Also it is an important axis of movement between the Crau-Camargue complex and the Alpilles is approached by this sector (see map p19).

This structure is to be renovated as part of the redevelopment of the RN113 motorway into the A54 (enlargement of the road). The road to be crossed is the RN113, the road bridge allows traffic to move in both directions : to the north, the motorway interchange no.10 of the RN113 in the direction Saint-Martin-de-Crau ; to the south, access to the business zone of Saint-Martin-de-Crau. The structure is used by heavy trucks daily in both directions of movement.



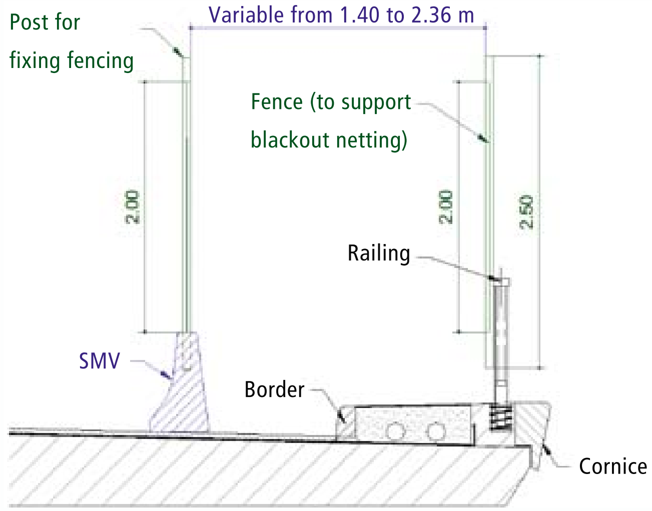
Localisation of the site of the structure. © S. Fourasté, IGN, Google Earth

Configuration of the experimental corridor

It results in a corridor converted into a bank* following one of the pavements of the structure and part of the road surface. The corridor is equipped with coverings* that protect against wind, light and that reduce noise.

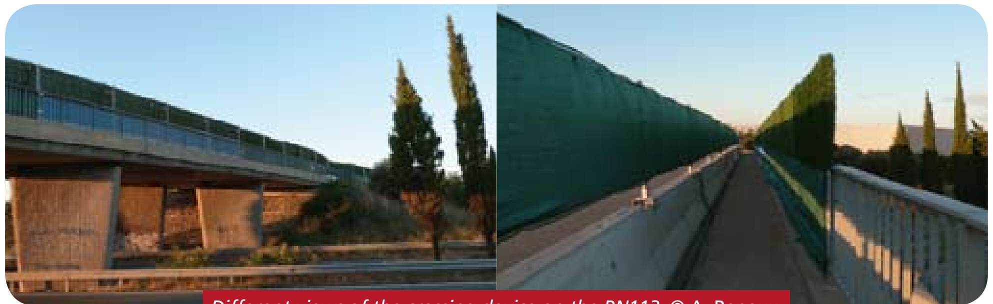
These coverings, an interim arrangement, consist of :
- bank side : a wire fence of a type found on building sites, attached to the existing railing* of the structure,
- road side : a wire fence of a type found on building sites supported by a concrete lane divider (GBA*).

The shielding device is fixed onto mesh fencing.



Cross section of the experimental corridor.

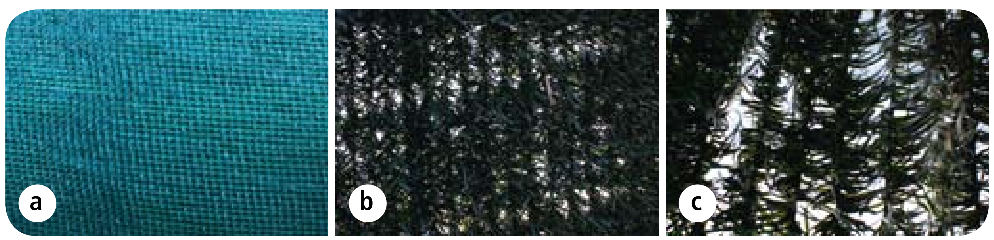
Equipment selected for this experimental device should meet road safety requirements on and below the structure : ensure that the equipment does not tip onto the road, ensure the functionality of the retaining guardrails, track separators (GBA) to meet normal road safety standards, etc.
This structure is a specific prototype, flexible enough to be modified accordingly when assessing the behaviour of bats. The choice of equipment commonly used on civil engineering projects responded to this need : the GBA makes it possible to adjust the width of the device and to change it, if necessary, to test several widths in order to define the ideal gateway type for bats. However, to maintain the circulation in two directions on the road bridge according to the wishes of local elected officials, the maximum width available for the device has been limited to 1.56 m. Therefore, only this modality of corridor width for bats was finally tested during the observations (a narrow corridor is less favourable for bats).



Different views of the crossing device on the RN113. © A. Renaux

The bat corridor is 58 m long. An extension of the outer wall was put in place towards the south of it to reduce the discontinuity between the structure and the surrounding vegetation. This extension was limited to fifteen meters for reasons of visibility and the safety of road users.

To mitigate the light effectively, the covering used must have a 90% blackout capability. During the procurement, a covering with 100% blackout capability was chosen (photo a) but it proved ill adapted to the site conditions : it is a very windy environment, it's strong resistance to wind caused a risk that it would tear off and land on the road. After a breakage of the retaining device and the tearing of a portion of the 100% blackout covering during an episode of strong wind (more than 80 km/h), an adaptation had to be made. The choice was an artificial hedge which has a blackout capacity of more than 90% without wind (photo b) and lower when it is windy (photo c) (Note, there are less bats moving around in strong wind).



Different blackout coverings used : a) 100% blackout covering used first, b) artificial hedge with no wind, c) artificial hedge in strong winds. © S. Fourasté

Conditions of road use in the presence of an experimental device

The act of installation of such a device on a road, changing traffic conditions (lanes reduced) must be accompanied by a temporary signal to warn road users, as well as enhanced monitoring by the manager to ensure proper maintenance of the device throughout the duration of the installation (stability of the equipment, retainers, etc.). This is for the safety of road users.

As well as provisional markings on the ground, information panels and notices about the changes to the road have been put in place.
Information boards made the LIFE+ Chiro Med program were also erected during the experimental period.

Different road signs indicating the site of the experimental device. © S. Fourasté

Constraints during the study

Urbanisation around the site and light pollution

The structure is one of the access points to the business zone of Saint-Martin-de-Crau. The economic centre is expanding and new buildings were constructed just south of the structure between the observations of bat behaviour without the device, in 2011 and the experimental phase with the device, in 2013.
These industrial buildings equipped with exterior lights generate significant light pollution and therefore a non negligible affect on the use of the site by bats. This difficulty was sufficiently anticipated to conduct advocacy work with the municipality, the urban community and the industries concerned to reduce (number and intensity) and redirect lighting which was displaced by wind (towards the ground rather than horizontally or toward the sky) to perform observations in conditions as close as possible to the same conditions as the initial observation (A6 and E5).

Light pollution to the south of the structure used for the bat corridor experiment before action taken by the industries on application by the GCP for better orientation of the lighting. Photo taken from the road bridge, north of the structure.. © E. Cosson

Wind

The study area is located in the corridor of wind which goes along the Rhone. It is therefore frequently subjected to strong Mistral winds from the north.

This climatic constraint means that the correct materials must be chosen and that they are attached in a fashion to withstand strong winds.

The first type of covering used had a major blackout capacity (100%) and was not perforated. It offered too much wind resistance and was ripped twice. This was replaced by a perforated covering whose blackout capacity was greater than 90% in no wind, and about 70% when it was windy. For a transitional facility, a lightweight covering with 100% blackout is ideal and inexpensive but must be perforated in areas with strong wind.

Stays consolidating the structure against the wind. © S. Fourasté

An "artificial hedge" materiel proved very suitable for local wind conditions.

The system for attaching the fence to the GBA is relatively conventional for this type of work and posed no problem. Particular attention was however paid to the fastenings on the guardrail side, opposite the bridge exposed to the wind, to ensure that the covering did not bend down into the path of the road to be crossed (RN113) or the road on the bridge. The extension of the device, on the south side, needed to be weighed down by concrete blocks and guy ropes to resist the wind.

Vandalism

The artificial hedge was stolen several times during the experimental phase.

Anti-theft devices exist (steel rope) but had not been anticipated at the outset of the project.

Finally, the cost proved to be more expensive than replacement of the hedge in the case of theft. No anti-theft system was implemented during the experiment after the first cases of vandalism and the artificial hedges were replaced. We had no further vandalism thereafter.

Vandalized device : hedge stolen © S. Fourasté

Installation Time

It appeared that the duration of the installation before evaluation was certainly somewhat short for bats to completely integrate with the device. The ideal would certainly be to evaluate such a device for 5 consecutive years to achieve final results.

The damage caused disrupted the correct operation of the device which remained incomplete (missing all or part of one of the walls of the corridor) for more than 50% of the time between its installation on March 22 and the end of September.

EXPERIMENTAL DEVICES TO HELP WITH ROAD CROSSING

Evaluation of the system

Method

A similar methodology to the evaluation of the audible warning system (*see* earlier in this guide) was applied by the Bat Group of Provence (GCP) at the bat corridor : 78 automatic ultrasonic recorders (AnaBat™) were placed during 24 nights distributed from early June to late August to identify the most popular areas around the site and identify the presence of the Greater Horseshoe Bat.

Evenings and mornings of observation were conducted from early June to late September 2013. They allowed the observation of the behaviour of bats at the device and in its direct proximity, by use of the thermal camera and to observe (direct eye contact) during the periods of night transit.

As for the audible warning device, Geoffroy's Bat, difficult to identify with AnaBat™ and capable of flying high, was not targeted by this assessment even though it did seem to use the bridge. The Greater Horseshoe Bat was the main target of this experiment. However, observations were conducted on all bats that visited the site during the observation period.

In addition, monitoring of mortality was made on the hard shoulder and the side of the RN113, 100 meters above and below the structure (co- financed by SNB - National Strategy for Biodiversity).

Results of behavioural observations

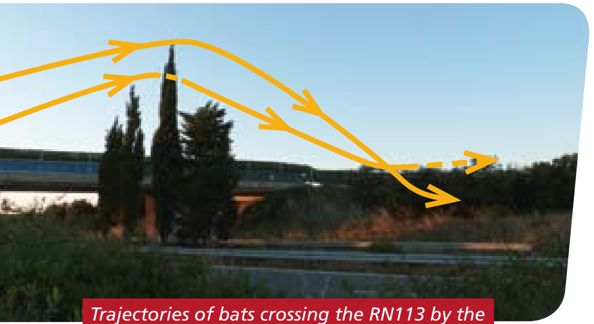
Only five Greater Horseshoe Bat were recorded and none could be directly observed by sight or with the thermal camera. There is no evidence to confirm whether the species crossed the RN113 at the device or not. However, the use of the site by the Greater Horseshoe Bat outside the nights of observation and placement of AnaBat™ is not excluded. Plots located on both sides of the device have been shown to be hunting grounds for the species. In addition, a study during autumn 2013 on behalf of the local network of ASF revealed a large amount of activity by the species in a crossing area of the A54 motorway located just east of Saint-Martin-de-Crau, less than 5 km from the device, in a run down suburban area. Greater Horseshoe Bats therefore cross the highway in this sector.

Species identified in direct vicinity of the device :

Distribution of bats contacts around the bridge. © Google Earth

- Greater Horseshoe Bat,
- Kuhl's Pipistrelle,
- Common Pipistrelle,
- Soprano pipistrelle,
- Nathusius's Pipistrelle,
- Savi's Pipistrelle,
- Serotine Bat,
- Common Bent Wing Bat,
- *Myotis sp.*,
- *Plecotus sp.*

EXPERIMENTAL DEVICES TO HELP WITH ROAD CROSSING

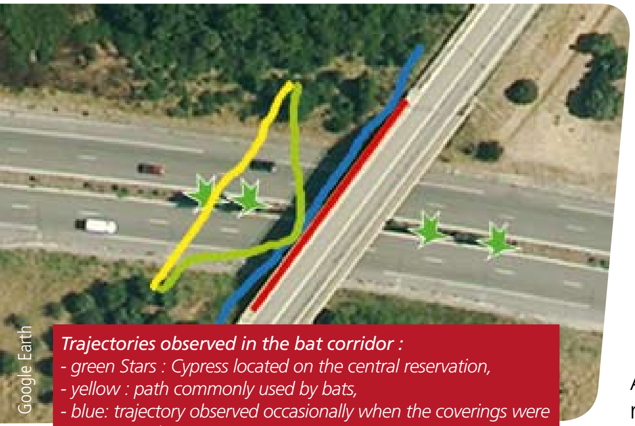


Trajectories of bats crossing the RN113 by the Cypress trees. © A. Renaux

Whether the device was complete or not, bats were observed predominantly to cross the RN113 by Cypress trees located on the central reservation to both sides of the device. These high trees act as relay points for the bats who can then fly high enough to cross the dual carriageway.

During the observations made with the device complete, some individuals very occasionally skirted the outer border of the device to cross the RN113 which had not been observed before.

Trajectory observed only when the bat corridor was complete. © A. Renaux



Trajectories observed in the bat corridor :
- green Stars : Cypress located on the central reservation,
- yellow : path commonly used by bats,
- blue: trajectory observed occasionally when the coverings were complete,
- green : trajectory observed more frequently after 4 weeks with no degradation of the device,
- red: bridge fitted.

After four weeks with the corridor device complete, changes in flight paths were observed more frequently with particular individuals beginning to cross the RN113 at the axis of the Cypress trees then deviating their trajectory to approach the experimental corridor above the central reservation, then moving again at the end of crossing to go back to the usual axis of flight taken after passing the Cypress trees. This behaviour was observed in both directions of crossing the RN113.

After five weeks in the presence of the entire corridor, new behaviours were observed : Individuals skirted around the device 1 m above the covering, some individuals dived between the walls of the corridor to travel in it for a few meters.

No individual was seen in the corridor along its entire length, however these results are very encouraging in relation to the use of the device by bats. It seems that the Cypress trees located on the central reservation provide a functional way, used by several species of bats, to cross the RN113. These tree relay points can limit bats mortality in this area (of the 88 dead bats found in 2010, none were found in this area) ; monitoring of mortality carried out in 2013, every 3 days, found a Common Pipistrelle killed in hunting and not in transit (insect still in his mouth) at the beginning of June. The device was not complete at this time.

These behavioural observations show that even if a functional flight axis is already used, if a more secure and reliable passage is implemented, bats eventually adopt and use this structure to facilite road crossing. Despite a lack of clear proof in the case of this experiment, we remain confident that the Greater Horseshoe Bat and Geoffroy's Bat will use this type of device.
A similar device produced the first positive results in 2013 on the Bourges bridge, fitted on a permanent basis with a covering 1 m in height which was only attached to the side railing.

Cost of the experimental device

The corridor for bats consists of two walls of 58 m long. The cost of installation was 13,403.50 € HT (16,030.59 € TTC) (HT without tax - TTC with tax included) of which :

- fence hire : 2,106 € HT (2,519 € TTC) (15.6 €/m²),
- hire concrete blocks used on the road side : 2,730 € HT (3,265 € TTC) (45.5 €/m²),
- purchase of blackout covering : 3,307.5 € HT (3,956 € TTC) (15,75 €/m²),
- horizontal and vertical signal panels (road safety and information) and set up cost : 5,260 € HT (6,291 € TTC).
- an extension of the outer wall of about 15 m to the south resulted in an additional cost of 1,331.25 € HT (1,592.18 € TTC),
- the covering had to be modified on the railing side for an amount of 899.79 € HT (1,076.15 € TTC). This expenditure was repeated again to complete the device after it was vandalized (same amount).

The total of the expenses relating to the experimental corridor is 16,534.33 € HT (19,775.07 € TTC).

Note that operations connected to the monitoring and maintenance of the device were widely performed by the manager of the road (DIR Mediterranean), to limit the overall cost of operation.

Evaluation of the cost of a permanent corridor

The cost of a permanent crossing over a road, of a type with opaque walls attached to the structure, can be estimated on the basis of ratios of the order of from 500 € HT/m² to 700 € HT/m².

The enlargement of a structure to allow a corridor to pass over it is more difficult to estimate, since this can be more or less more complex to implement and the structure is not always easily adapted according to its type. Experience of this type of operation leads to an estimation of about 5,500 € HT/m² for enlargement.

A bridge dedicated to the passage of wildlife can also be considered, possibly built in the immediate vicinity of an existing structure. A ratio of 3,500 € HT/m² can be used for a preliminary study. Besides the fact that a new solution allows for flexibility in the geometric configuration of the passage, it is also sometimes cheaper than a widening project for an existing structure (structural complexity, operational constraints).

Any estimate obviously needs to be adapted to suit local site constraints. The manager(s) will validate the project in relation to road operating constraints, and a civil engineering feasibility study.

Assessment and prospects for improvement

This device to help bats cross the road is innovative and experimental, therefore needs to be adjusted and improved.

At the end of this experimental season, the results show, taken only over a few weeks, that the bats need time to begin to use the structure. It seems to be necessary that the device is one a hard structure to ensure its stability in bad weather. The device must be constant and reliable in order to be adopted by bats. Furthermore, to confirm the effectiveness of such a device, it is necessary to increase the experimental timescale to cover several consecutive seasons. In fact, bats learn and the knowledge of their environment and flight routes made from year to year spreads to other individuals. A mid-term evaluation of a device that has remained in place for 3 to 5 years is highly desirable. Finally, to increase the blackout capability of the covering while maintaining a relatively low wind resistance, it is possible to double the artificial hedge : with no wind : 100% blackout, with wind ~90% blackout, but at the same time offers low resistance to wind pressure.

In addition, for this type of device which targets wildlife, either attached to an existing structure or a renovation, it is necessary to integrate work into the design so that it can be multi-purpose : useful for human movement and the displacement of wildlife. This may facilitate its acceptance. Thus, a bridge for bats may also be used as a foot bridge or a passage for cyclists, unlit of course !

As part of the redevelopment or construction of a site, if the structure of the site allows, the widening of a road bridge could be planned to accommodate the passage of wildlife/pedestrians/cyclists. It could then be protected from light by two walls creating a corridor over the "black" network, protected from light and facilitating the movement of bats. This physical boundary also protects pedestrians or cyclists from motorists.
There has also been a conception to create a lateral enlargement reserved for bats and non accessible to walkers, including humans. This lightweight structure would be attached to the side of an existing structure and is located above the road to be crossed. This type of development is technically feasible but there are constraints around their installation on operating routes in terms of security, for example, in the case of use by humans, despite a restriction.

If the bridge is not used by cars, it can be quite easy and inexpensive to install a structure of opaque walls to the side railings, ensuring that it connects at each end to the landscape. This system has already been used in experiments in France and is functional.

Greater Horseshoe Bat.

CONCLUSION

The LIFE+ Chiro Med program is part of a process of environmental redevelopment of the existing network under the Green Motorway Package and the Modernization of Infrastructure Program, designed to be in accordance with the Grenelle Environment. Thus, the experimental devices to help facilitate the crossing of roads by bats have been placed on the existing network in order to improve its permeability to biodiversity. Audible warning devices are permanent and destined to remain in place after the program. The experimental corridor constructed on a structure to be renovated was dismantled and may be rebuilt on a permanent basis as part of the work to come.

This experiment was also intended to demonstrate the value and ability of redeveloping existing bridges as bat crossings over older roads, where few environmental improvement projects are considered. It is on these existing roads, where wildlife is killed every day, that it is urgent to improve the situation before the local bats populations disappear. With current knowledge, it is expected that new road projects will incorporate the necessary passages for wildlife, in sufficient numbers, during their conception.
A good initial design will include limiting the additional costs of modifying existing infrastructure (integration of oversized culverts as often as possible, modifying the design of structures such as bridges over new roads, transparent land acquisition law to sustain the landscape at crossing points, etc.).

The first conclusions from the actions of the LIFE+ Chiro Med experiments have already been fed into the preliminary studies for the motorway bypass of Arles, which were amended after proposals to reduce the impact on bats : improvements to existing structures (fixed coverings) reserved lane on an existing structure (width 3 m), dedicated bridge, landscaping designs for guidance, oversized hydraulic structures with vertical release of more than 2 m, management of the landscape next to roads, etc.
Moreover, these experiments will feed future local projects, and also those outside the Camargue, under the framework of redevelopment or construction of infrastructure.

The experimental devices used here appear to be effective tools to improve crossing conditions for bats on roads in the Camargue. However, they must be adapted to each local context (land and species). This guide presents specific case studies but this is not a recipe of functional standard features for all circumstances !

Each situation is unique and must be subject to prior study to identify the habitats of the threatened bats and the points of conflict on the territory, and to propose solutions and suitably adapted devices.

Memos

To guide your projects to improve the permeability of road infrastructure for bat, you can consult these Memos !

Also note the planned publication of a useful guide entitled "Chiroptères et infrastructures de transport" which is edited by the SETRA.

THE INSTALLATION OF AN AUDIBLE WARNING DEVICE FOR BATS

If a sector is identified as a black spot or area of conflict between traffic and bats :

- favour the construction of a large underpass (over 3x3 m), which is more secure and suitable for the majority of species of bats (*see* SETRA Guide 2008) ;
- identify the needs of the crossing depending on the target species :
  - characteristics of the crossing area (width of the area , the landscape structure near the area...),
  - behaviour of bats in the area ;
- analyze the auditory sensitivity of the target species (identify frequency range sensitivity-behavioural audiogram of the species) ;
- study the characteristics of the road : acoustic characteristics of the current road surface coating ;
- identify the coating (or other device) that will generate a suitable audible warning adapted to the target species. Sound frequencies should be inaudible to humans to limit disturbance ;
- identify the manager of the road and gather information on operating constraints, maintenance and management : areas that must be maintained and other that are available, planning of works, minimum distances from homes, compatibility of the device with the Highway Code, etc. ;
- validation of the principles of the project by all stakeholders ;
- integrate the installation of the device into a repair of the road surface to limit cost of installation ;
- Set a schedule compatible with the realization of the lifecycle of the species (periods of displacement) and the constraints of the work on the road managers (night work, availability of intervention teams to secure the work area, schedule to limit inconvenience to road users or to reduce the likelihood of accidents).

THE INSTALLATION OF A DEVICE ON A STRUCTURE ABOVE THE EXISTING CROSSING

If an existing structure is identified as a potential corridor for bats above the existing infrastructure :

- define the needs of the crossing depending on the target species or number of species :
  - characteristics of the corridor to put in place : useful width of the passage for the corridor, protection of the passage (vis-a-vis light pollution, pedestrian and cycle path...), materials / surfaces preferred (decking...),
  - landscaping of the surrounding area (connect the Green and "black"networks that exist) to establish an ecological continuity ;
- attach the corridor to a structure : do you need to provide a railing, do you need a reserved lane? ;
- investigate the potential of the structure : existing cross section, design of the structure to support the addition of equipment (too heavy ?), structure (pathology ?) ;
- identify the different managers (structure, road(s) to be scoped(s) and crossed(s), networks, etc.) and take account of their operation, maintenance and management constraints : uses to maintain, allowances available, planning for interventions ;
- obtain the validation of the principles of the project by all the stakeholders ;
- define a schedule of work compatible with the life cycle of the species (travel periods) and constraints between operating (night work, availability of intervention teams to secure the work area, good times to limit inconvenience to users, or reduce the risk of accidents).

THE USE OF STRUCTURES AS ECOLOGICAL CORRIDORS

- Overpass (example LIFE+ Chiro Med)
  - *on an existing structure* : adaptation of the structure by changing the cross section, changing the initial use, addition of equipment, enlarging, etc., the project remains constrained by the potential of the existing structure to support a new use ;
  - *on a new structure* : define sufficiently in advance of the start of the project the right width of the corridor, and specific equipment (height of the covering), decking, blackouts, as well as the connections with the edge of the structure.

- Underpass
  - *under an existing structure* : hard to change the existing structure (geometry of passage), but possibility of working at the edge and on the naturalization of the ground beneath the structure ;
  - *under a new structure* : define sufficiently in advance of the start of the project the geometric needs of the corridor and facilities above and below it ;
  - the creation of a passage under an existing road can be done by microtunnelling with a sufficient diameter of more than 150 cm, with specific adaptations for multi wildlife use (low slope, soil quality, vertical walls, etc.). The creation under a road built on rubble makes it easy but it is possible to do so under a road with little or no rubble provided the start of the microtunnelling is pulled back or dug down in trenches when water level constraints allow.

Apron : part of a bridge that carries the road, including and all weight bearing structures and road surfaces.

Biodiversity : refers to the diversity of living things. This diversity is expressed and plays a role in all organizational levels of life : diversity of species, diversity in a species, between individuals at any given moment, ecological diversity, the associations of species in a given environment. (source : National Biodiversity Strategy 2011-2020).
Variability among living organisms of all origins : terrestrial, marine and other aquatic ecosystems among others, and the complex ecology of which they are part ; including diversity within species, between species and of ecosystems (source : Convention on Biological Diversity).
Diversity of living organisms, which is assessed by considering the diversity of species, that of genes of each species , as well as the organization and distribution of ecosystems. Maintaining biodiversity is an essential component of sustainable development. (source : vocabulary of the Environment published in the Official Journal of 12 April 2009).

Breeding Roosts : from June to September, females gather in birthing colonies and give birth to their single young of the year (from mid- June to late July). Sites occupied by these colonies are characterized by a high temperature, the absence of air flow, the absence of disturbance and abundant food nearby. The most favourable sites are roofs and attics, barns, stables, cracks in trees, warm caves...

Contracting authority / petitioner : a contracting authority, also called petitioner or licensee is a physical or moral person, public or private, who initiates a project and is responsible for the application for authorization or declaration. The contracting authority can be public (ministry, local government), broader public (mixed company) or private (private company). Corresponding : petitioner, bidder, project leader, promoter, developer.

Covering : wall that obscures the light, more or less perforated.

Ecological or biological corridor : space between ecosystems or habitats, which allows the movement of species and genetic mixing of populations. (source : Vocabulary of the Environment, published in the Official Journal on 1 February 2011).
This is for example the case of riparian corridors or riparian woodland (plantations located along a water course) which serve as habitats, refuges and corridors for many species.

Ecological connectivity : existence of a functional link which binds or connects elements (natural or semi-natural habitats, buffer zones, biological corridors) between themselves, from the point of view of an individual, of a species, or a population, for all or part of their life cycle, for a given moment or for any given period. This concept reflects the possibility (and its speed) for an individual or a population to migrate to complete its life cycle (growth, food) and interact with other individuals or populations (reproduction).

Ecological continuity : the ecological continuity of a water course or a portion of space defined by the free movement of species and flow of materiel (*eg.* for water courses, the smooth natural transport of sediment) (source : guide No. I of The Green and Blue Network).

Ecosystem : functional ecological unit formed by the biotope and biocenosis, in constant interaction. (source : vocabulary of the Environment published in the Official Journal on 4/02 /2010).

EUROATS : this agreement has the aim of protecting 36 species of bats identified in Europe, through legislation, education and conservation, as well as international cooperation between the signatory countries and other European governments. The signatories to the Eurobats Agreement committed to a common goal: the conservation of the European populations of bats.

Fragmentation of natural areas : fragmentation of natural areas leading to the isolation of plant and animal populations on the one hand and the habitats on the other. This isolation degrades and weakens the different fragments and may eventually challenge the sustainability of some species or natural habitats.

GBA : (Glissière en Béton Armée in French) reinforced concrete.

Green Motorway Package (PVA in French) : on January 25, 2010 , the State signed the Green Motorway Package with several motorway concession companies. In return for the extension of their concession contract by one year, they have committed to spend € 750 million over 3 years to redevelop, from an environmental point of view, the existing network. This program, which aims to make greener highways, focuses on five areas as follows :

- the protection of water resources,
- protection against noise,
- taking into account biodiversity and TVB,
- eco-renovation of rest areas and services,
- the reduction of CO_2 emissions.

Habitat, Priority Habitat : place where the species and its immediate environment are both abiotic and biotic. (source : Dictionnaire encyclopédique de l'écologie et des Sciences de l'Environnement - François Ramade).
A natural or semi-natural habitat is an environment that meets the physical and biological conditions necessary for the existence of a species or group of animals or plants. (source : Natura 2000).
The habitat of a species is in the midst of the life of a species (breeding area, feeding zone, hunting area, etc.). It may include several natural habitats. (source : Natura 2000).
A priority natural habitat within the meaning of Directive 92/43/EEC, is a type of habitat in danger of disappearance, present in the territory of the European Member States to which the Treaty applies, the conservation of which the Community has particular responsibility for given the importance of the natural range within this territory. Types of priority natural habitat are listed in Annex I to the Directive.

Habitats Directive Fauna and Flora (Directive 92/43/EEC of 21 May 1992) : a regulation made by the European Union to maintain the biological diversity of the Member States by conservation of natural areas and species of fauna and flora of Community interest. The Natura 2000 network brings together these sites of community interest consisting of Special Conservation Zones defined by the Habitats Directive, and Special Protection Zones as defined by the Birds Directive (Directive 79/409/EEC of 2 April 1979). Annex II the DH list of species whose conservation requires the designation of Special Conservation Zones.

GLOSSARY

Hibernation Roosts : bats hibernate in natural or artificial cavities, such as caves, mines, tunnels, basements, old quarries, cracks, holes in trees... These roosts offer them total darkness, absolute tranquillity, a cool stable temperature which protects them from frost, light ventilation, and humidity generally close to saturation to avoid their wings drying out.

LOTI Report : law 82-1153 Orientation of Inland Transport (LOTI in French) of 30 December 1982, involves the production of socio -economic and environmental assessments 3-5 years after implementation of major transport infrastructure. The purpose of such a review is to analyze and explain the differences between the economic and social assessment established at the end of the public inquiry and actual observations after the commissioning of the infrastructure. It also verifies compliance with the commitments of the State made at the end of the public inquiry. Furthermore, this confrontation provides useful feedback that improves evaluation methodologies ex ante (evaluation at the end of the public inquiry) and informs future choices.

Modernization of Road Networks Program (PDMI in French) : these programs cover all operations for the modernization of the existing road network without creating new features and without substantially increasing the capacity of the network. It was established for the period 2009-2014, taking into account new guidelines that emerged from the Grenelle Environment. They thus reflect the national pattern of transport infrastructure established by the law of 3 August, 2009, relating to the implementation of the Grenelle Environment.

Objectives Document (DOCOB in French), Natura 2000 : reference document which establishes a diagnosis and defines management measures to be implemented for each Natura 2000 site. From a consultation process, it comes from a "negotiated" administrative law and not a unilateral procedure. (source : Natura 2000, the Ministry of Sustainable Development website).

Regional Schema of Ecological Coherence (SRCE in French) : this is a new schema of development of territories and protection of certain natural resources (biodiversity, ecological network, natural habitats) designed for the good ecological status of water required by the Water Framework Directive. The SRCE is not enforceable against third parties, but some documents must be "compliant" or "compatible" with it, to reduce the ecological fragmentation of territory, for a good ecological renewal of the status of natural habitats.

Services rendered by ecosystems or eco-systemics : these are the direct or indirect benefits that man derives from nature; they include the provision of services (food, water, timber, fibre, etc.), regulating services (climate, floods, disease, wastes, pollination, etc.), self-maintenance services (soil formation, photosynthesis, nutrient recycling) and cultural services (recreation, aesthetic, spiritual).

Side Railing : protective barrier placed along a bridge.

Species : basic taxonomic unit in the classification of the living world. A species consists of all individuals belonging to breeding populations who exchange freely their gene pool but, in contrast, do not breed with individuals constituting of populations of neighbouring taxa belonging to the same population. (source : Dictionnaire encyclopédique de l'écologie et des Sciences de l'Environnement - François Ramade).
Priority Species : a species of community interest at risk and the preservation of which EU has a particular responsibility for, given the importance of part of its natural range within the European territory of the Member States. Priority species of community interest are listed in Annex II of the Fauna-Flora-Habitat Directive 92/43/EEC.

The Financial Instrument for the Environmen (LIFE+) : the LIFE+ program funds projects that contribute to the development and implementation of environmental policy and law. This particular program facilitates the integration of environmental concerns into other policies and, more generally, contributes to durable development.

Tragus : projecting appendage inside the ear.

Transit Roosts : these are shelters occupied by bats more or less temporarily in spring and autumn. They are quite varied (sheds, barns...), but their conditions are not conducive to reproduction. Their role is still unknown, they often provide a stopping point between winter and summer roosts, and house a large variety of numbers.

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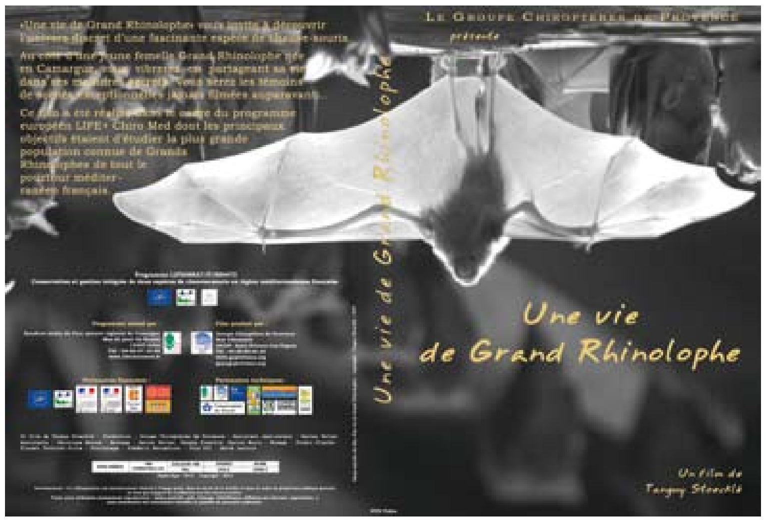
The reports of LIFE+ Chiro Med on different actions are available on the website :
www.lifechiromed.fr



Between 2010 and 2014, Tanguy Stoecklé directed the film
"Une Vie de Grand Rhinolophe / Life of the Greater Horseshoe Bat"
under the framework of the LIFE+ Chiro Med program. This film is dedicated
to the Greater Horseshoe Bat and tracks a female and her baby throughout their lives.
You will see exceptional scenes never filmed before.

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The Technical Guides by LIFE+ Chiro Med

This collection was created by the LIFE+ Chiro Med program coordinated by the Camargue Regional Nature Park is intended for a specialized audience.

Each guide addresses a specific theme resulting from the synthesis and results of actions undertaken by the European program LIFE+ Chiro Med

The other guides

Technical Guide No. 2

Management of bovine parasites and wildlife coprophagia

Technical Guide No. 3

Developing roosts suitable for breeding

Technical Guide No. 4

Conducting winter surveys in cavities

Technical Guide No. 5

Elements of area conservation management

Technical Guide No. 6

Imaging techniques in the service of conservation