Technical Guide No. 3

Developing roosts suitable for breeding

LIFE+ CHIRO MED Program

2010–2014

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

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

The Greater Horseshoe Bat and Geoffroy's Bat

Cover photo : V. Hénoux.

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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 XXth 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.

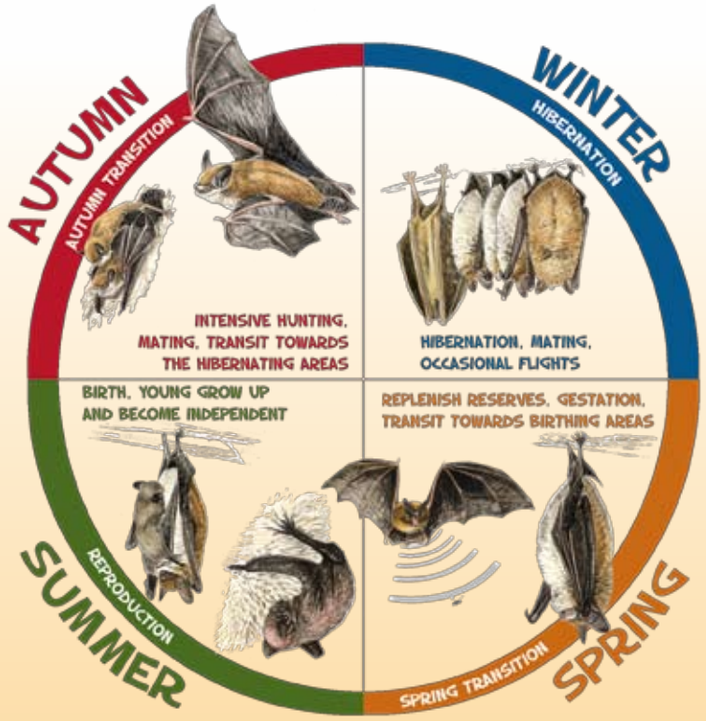
All bats are protected by law by means of :

- **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 north-west 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").

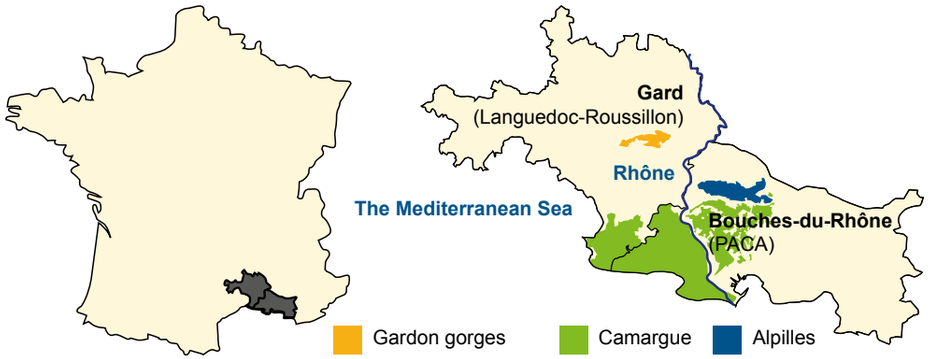
Distribution : The species shows a very heterogeneous distribution over its entire range. In France there are strong disparities depending on the region. **The south of France** has a low population in winter but a **high population in summer**.

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".

ROOSTS – ESSENTIAL HABITAT FOR BATS

A vital need

Like most animals, bats need **shelter to be protected from weather and predators**. They do not build these shelters but those that their environment offer them.

With a very high metabolism, bats seek to save energy constantly. They adopt several strategies to do this depending on the season and their biological needs. Pregnant females seek a warm roost that allows them to reduce their expenditure related to **thermoregulation*** and group themselves into colonies to increase the effect of heat for the group (*see* photo 1).

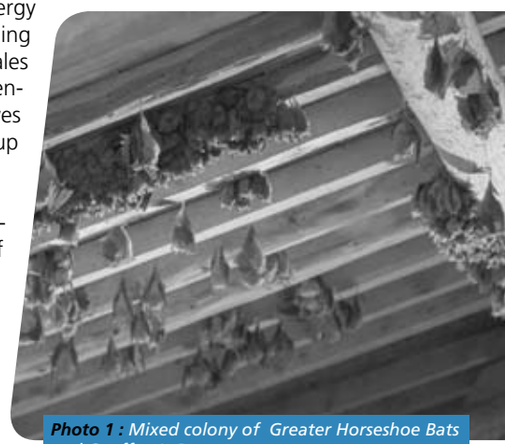
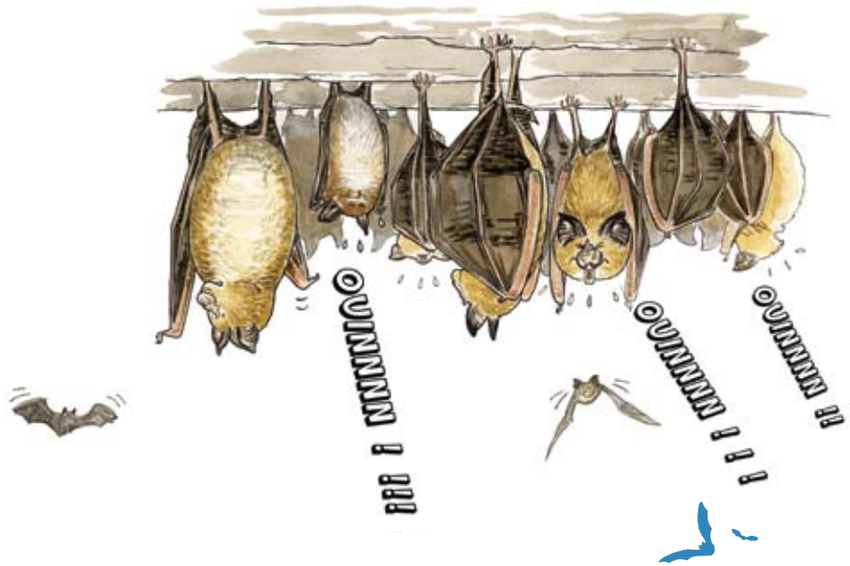


***Photo 1** : Mixed colony of Greater Horseshoe Bats and Geoffroy's Bats.*

Several species are often associated together so each benefits from the body heat emitted during various stages of development (BARATAUD & AULAGNIER 2012). This is the case in the Camargue area where many colonies are mixed, consisting of Greater Horseshoe Bats and Geoffroy's Bats. **Optimum heat in the breeding roost makes for good conditions during the course of gestation, and the vitality of a colony by improving the growth rate of juveniles and allowing the vigorous development of females adapted to pregnancy as adults**. Conversely, in the absence of a suitable roost, a cold spring may cause delayed parturition, which will result in increased mortality in the young and decreased reproductive success later (RANSOME 1998, RANSOME & HUDSON 2000). Exceptional cases of collective abortions or abandonment of the young have been observed.



Roosts for which biological functions ?

Some bats are fissuricoles* : they look for narrow roosts, crevices of various kinds. The Greater Horseshoe Bat and Geoffroy's Bat are called species known as "**Volume**" species : they roost in areas in which they can fly and move in three dimensions. However, Geoffroy's Bat willingly shows a fissuricole tendency (*see* photo 2) or uses **micro-roosts***. Several roosts are used during a life cycle* (*see* Table 1, and Technical Guideline No. 5 "Elements of area conservation management") and the observations allow us to recognize their functions (Schofield 2008).

Table 1 : Description of the types of roosts, their nature, terms of occupation and their functions for bats. Under the protection of species (Ministerial Decree of 23 April 2007), these roosts are broken down into habitat of a species such as "breeding site" (BS) or "rest area" (RA). Note that the same roost can have many ecological functions.

Types of roost	Functions	Periods of occupation	Individuals	Nature
Breeding roost (BS)	Gestation, birth, feeding, rest, flying exercises.	DAYTIME (adults and young). NOCTURNE (young and some adults). Middle of spring to late summer..	Several dozen to several hundred, awake, a presence of young left by parts by their mothers to go hunting.	**EPIGENETIC*** Hot parts of buildings, hollow bridges, military works. **HYPOGEOUS*** Underground cavities, warm, not deep.
Satellite roost (BS linked to the main colony)	Resting, feeding, flying exercises.	DAYTIME Mid spring to late summer. NOCTURNE (sometimes the young).	Less than ten in general, a presence of young left by parts by their mothers to go hunting.	**EPIGENETIC** Hot parts of buildings, hollow bridges, military works. **HYPOGEOUS** Underground cavities, warm, not deep.
Hibernation roost (RA)	hibernation, couplings .	DAYTIME and NOCTURNE Winter.	1 to several hundred, in hibernation.	**HYPOGEOUS** Cellars, underground, caves cold and wet bridges. **EPIGENETIC** Rare but occasionally observed in the Camargue (bunker).
"Swarming" or coupling roost (BS)	Mating, much flight activity.	NOCTURNE Autumn and early winter, in the middle of the night.	Many in the middle of the night, coming from dozens of kilometers away, active flight, pursuits, mating.	**HYPOGEOUS** Little known in the two species, the Greater Horseshoe Bat does not seem concerned **EPIGENETIC** Tunnels.
Spring transit roost (BS)	Gestation, rest before the gathering of the breeding colony.	DAYTIME Spring.	Groups + or - amount of females pregnant or not pregnant, active or in lethargy.	Similar nature of the breeding roosts, hot early in the season.
Inter-season transit roost (RA)	Rest during inter-seasonal placement, lethargy.	DAYTIME autumn and spring.	Groups + or - amount of both sexes and all ages, often in lethargy.	**EPIGENETIC** or **HYPOGEOUS** Buildings or cavities, not hot.
home rest (RA)	Resting, rooming, digestion.	NOCTURNE from spring to autumn, during hunting season.	1 to several individuals.	**EPIGENETIC** most often.

Photo 2 : *Breeding colony of Geoffroy's Bats in a barn at Gard.*

Roosts have become rare

Before the advent of Man, many bats in temperate climates, including the Greater Horseshoe Bat and Geoffroy's Bat were probably in caves throughout the year. In areas such as the Gardon gorges or the Alpilles, they could find a variety of cavities adapted to their individual needs. Gradually, changes in the landscape and human activities have affected the quality of these roosts, or they have disappeared, undermining bat populations. As the environment is degraded, the population declines which has an insidious effect on cave roosts : in reducing the size of the colonies, the heat emitted by the group is correspondingly reduced, meaning the bats can no longer find the optimal conditions for their offspring, and maintain their numbers. (Ransome 1998, Ransome & Hudson 2000). **Thus, in addition to the rare cavities that are naturally favourable, bats have benefited from another source of shelter in expansion : human constructions**.

Today, these substitute roosts have a reduced availability for bats : Underground sites are closed for safety, buildings and structures are renovated and inaccessible, illuminated or destroyed. **Finding a suitable roost has become a daunting task for a colony.**

The construction in the Carmargue sector

The Camargue sector generally, because it is has a large number of insects, and because it has many roosts in buildings, is conducive to the maintenance of large populations of bats. During the evolution of human activities in the geographic area, mechanization has been a source of potential breeding roosts for certain species of bats. In effect there are many properties, buildings used to house farm workers that are no longer in use today and offer various large spaces that can accommodate a colony of Greater Horseshoe Bats and Geoffroy's Bats (*see* photo 3).

Within a farm building, bats of various species can shelter in many places, cracks or large spaces (*see* Figure 1).

Photo 3 : *Agricultural Building not in use. The bats use the various areas in these buildings as shelters, each room can be occupied at different times of the life cycle. Example, an old forge, 2011.*

The current context of **buildings in the Camargue creates potential spaces for bats to roost.**
Moreover, the tourist attraction of the sector promotes the renovation of many buildings to create second or main homes. It is therefore appropriate to propose, in the heart of this dynamic, the conservation of a sustainable network of shelters for bats.

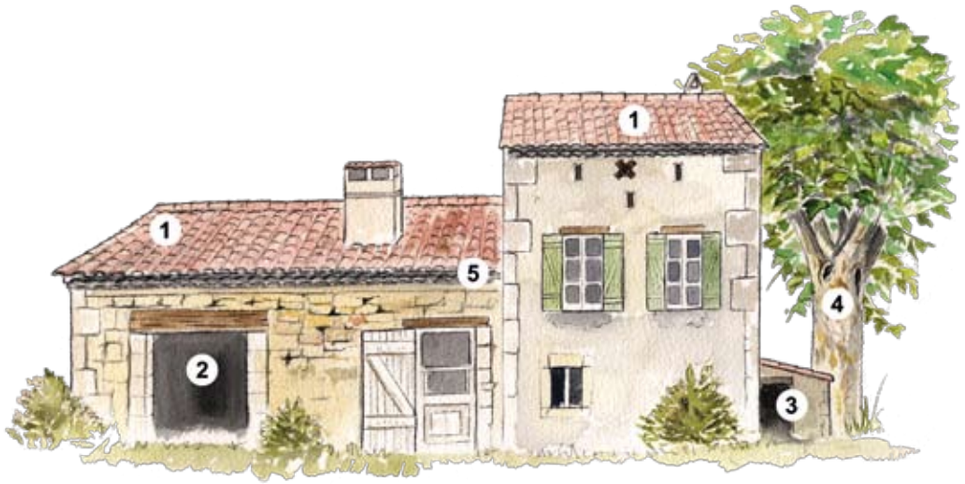


Figure 1 : *The various places where bats can shelter in a typical building in the Carmargue. The fissuricoles species roost under the tiles (1) or behind the shutters, "volume" species use the attic (5), the barns (2) or outbuildings (3). Some tree species roost in tree cavities (4).*

Objectives of the LIFE+ Chiro Med program

LIFE+ Chiro Med enabled the implementation of various protective actions within a sector made up of the Camargue area, the Crau, the Alpilles and the Gardon, a sector called CCAG*. Several actions were aimed at improving a network of roosts catering for both species (*see* Table 2) thanks to development of existing roosts and the creation of new roosts.

Table 2 : Actions by the LIFE+ Chiro Med program linked to the development of roosts favourable for breeding.

Area of action	Goals	Related Actions
Roosts	Understanding the abiotic conditions in the breeding colonies occupied by the Greater Horseshoe Bat and Geoffroy's Bat in the Camargue.	A2
	To improve them, guarantee their peace and sustain their presence.	C1
	Develop roosts not occupied by bats to create favourable breeding conditions and host conditions.	C2
	Establish a convention of works and follow up with the owners to sustain the roosts.	A1
Evaluation	Evaluate the effectiveness of development work on the temperature of newly constructed roosts lodgings.	E4
Population monitoring	Monitoring bat populations in the occupied roosts.	E3

From the compilation of bibliographic data and knowledge acquired through LIFE+ Chiro Med of **5 roosts occupied by the Greater Horseshoe Bat and Geoffroy's Bat (A2, roosts named G01, G03, G04, G06 and G07)**, the technical elements that characterize the roosts favourable to colonies of these two species are presented.

Internal conditions and ambience

Temperatures

Requirements of the Greater Horseshoe Bat

The temperature is probably the most important parameter in the selection of roosts by the animals but preferences are not detailed. The energy cost of thermoregulation for the Greater Horseshoe Bat is at its minimum when the temperature in the roost is 25°C. At more than 40°C individuals suffer from the heat (Ransome & Hudson 2000). In a roost, the individuals are therefore situated in spaces which are not far from a **"Comfort" temperature range**. In the Camargue where scientific studies have been conducted (A2), **this range is between 21 and 33°C** for the Greater Horseshoe Bat. Below 21°C, the bats congregate in tight swarms to increase their heat and above 33°C, they move and seek a cooler place. There is a temperature close to 30°C beyond which mothers are separated from their young usually positioned on their stomach. This behaviour reflects discomfort and, if the exact value of this threshold cannot be determined precisely, it seems important to keep the temperature below 30°C. This thermal amplitude of comfort is sought by the animals during the day, but it is also essential at night. In fact, the young who are unable to regulate their internal temperature in the days after birth, are left alone in the roost while their mothers go hunting. They cannot rely on the heat of the group, it is the roost itself that must provide the heat.

Thermal characteristics of occupied summer roosts

The action A2 has shown that, in the summer, the three roosts studied (G01, G03 and G04) provide, in the places occupied by bats, an average temperature of 26-27°C during the day and 22 to 27°C overnight (*see* Figure 2). The G01 roost seems more favourable as it offers a range of temperatures not far from the comfort range, day and night. In the other two houses, especially G04, the temperature can exceed the range of comfort and reach 34°C. This overheating phenomenon in the summer is common in buildings in the Camargue, but in spring the rise in temperature can be slow due to the prevailing winds.

Springtime thermal characteristics of occupied roosts

Bats are therefore looking for roosts that offer not only comfortable and consistent heat in summer but also that warm up early in the season, the gestation period (from April in the Camargue).

The results of action A2 show that the occupied roosts meet this requirement (*see* Figure 3). Between May and June, the average in roosts G01 and G04 is already 21°C during the day and night. However, the roost G01 is the most favourable. In fact, it offers a range of temperatures well adapted for bats (15-33°C) while the G04 house shows larger extremes in particular low temperatures during the day (10°C) that can lead individuals to change roost.

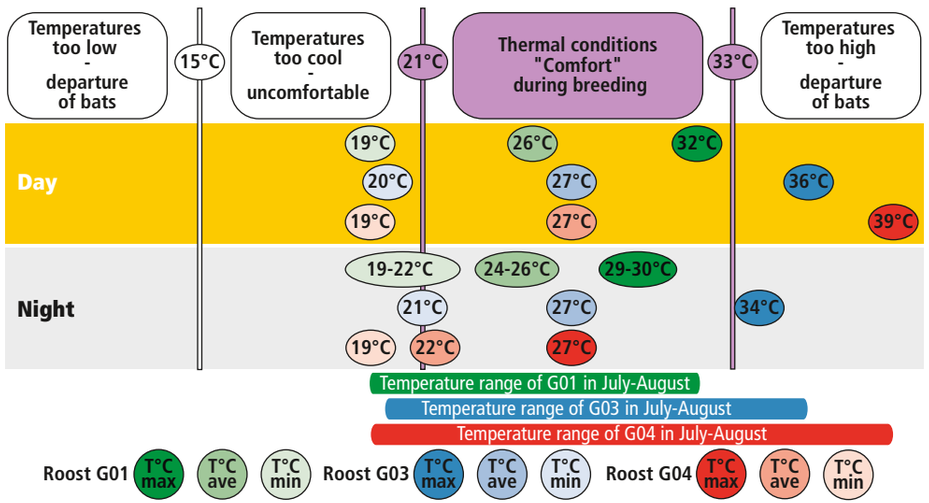


Figure 2 : *Characteristics of 3 roosts (G01, G03 and G04) in relation to the comfort temperature ranges of the Greater Horseshoe Bat in summer (July-August).* *During the day (yellow line) 3 roosts have an average at the centre of the range of comfort (comfort = 21-33°C), with extremes of 19°C to 39°C. Night (grey line) averages ranged between 22 and 27°C, and the extremes of 19-34°C.*

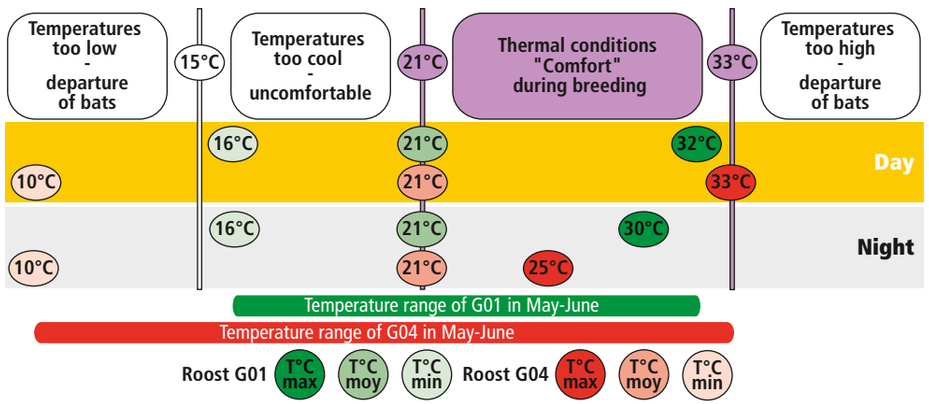


Figure 3 : *Characteristics of 2 roosts (G01 and G04) in relation to the comfort temperature ranges of the Greater Horseshoe Bat in spring (May-June).* *During the day (yellow line) the 2 roosts have an average minimum within the range of comfort (comfort = 21-33°C), with extremes of 10 to 33°C. At night (grey line) averages remain at 21°C, and the extremes range from 10 to 30°C.*

Know the comfort temperatures for bats

Because of their mobility within the roost, and their reactions to thermal conditions, Greater Horseshoe Bats have been used as a model for estimating temperature comfort. Greater Horseshoe Bats and Geoffroy's Bats are often in close proximity and determined values can certainly be generalized across the two species.

Colonies of bats move within the roost during the day to stay in a thermally comfortable environment. It is feasible to evaluate their thermal requirements by coupling temperature measurements with regular looks to see the locations and the disposition of individuals. This analysis involves creating a grid with markers showing the occupied space, as well as knowing the ceiling surfaces (*see* photo 4).

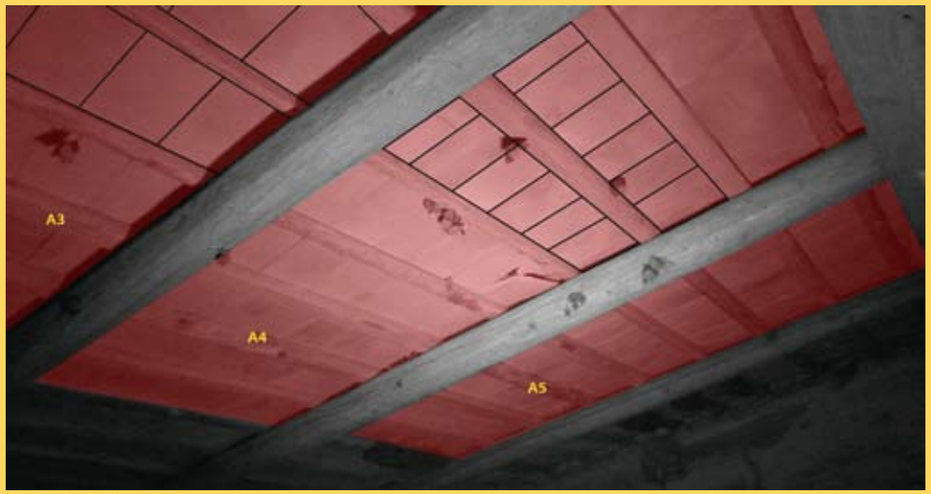


Photo 4 : Grid representing the space occupied by the colony in the roost G01. *The roost has been divided into several spaces between the beams encoded A3, A4, A5... (areas in red). The unit of surface chosen is each parefeuille* of the roof, whose surface area is 0,084 m2, represented by a black grid (top left).*

The principle (A2) is to relate temperatures to other parameters such as the absence or the presence of individuals, location of groups (see photo 5), the density ofindividuals, the proportion of individuals in tight groups, and the position of couples mother-young (joined or separated).

Photo 5 : *Colony of Greater Horseshoe Bats and Geoffroy's Bats in a building.*

The LIFE+ Chiro Med in numbers

Four roosts housing a colony were evaluated with 6 weather stations and 9 automatic digital cameras over three years as part of the action A2. A total of 12,000 records of temperature and humidity were taken, as well as 20,000 photographs. A detailed protocol was developed for the technical production, the processing of data and analysis in this type of study (*see* technical report A2).

Thermal inertia*

In the CCAG sector, during the breeding period, bats must find **roosts able to absorb and mitigate the excessive summer heat of midday**. The roost G01 seems to have this capacity (*see* Figure 4), called **thermal dephasing***. The temperature of the roost remains in the range of comfort, even when the outside temperature is at its peak between 14:00 and 17:00 at over 32°C. In addition it has spaces in low areas where the temperature is maintained at 27-29°C. The crowns of trees adjacent to the building play an important role in mitigating the direct sunlight on the roof. Conversely, the roost maintains a comfortable heat when the temperature drops between 00:00 and 06:00.

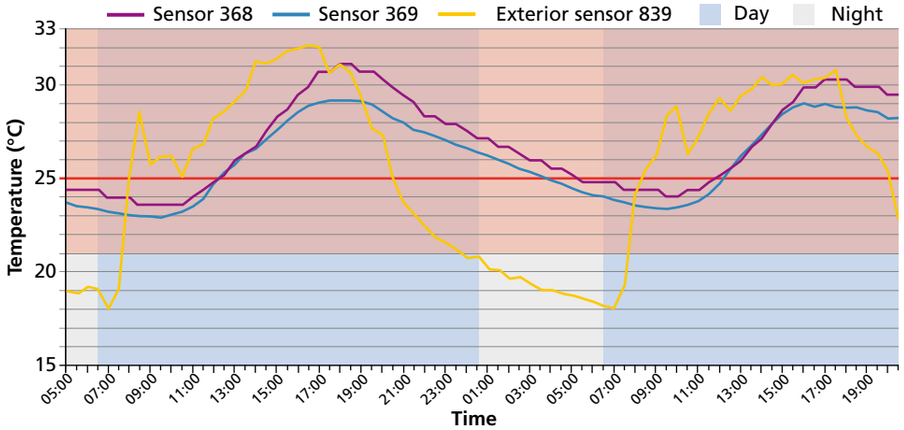


Figure 4 : Evolution of the temperature of roost G01 between July 31 and August 01. *The comfort temperature range is represented by the pink zone (21-33°C). The temperature of 25°C, above which the effect of thermoregulation is minimal, is represented by a red line.*

There are also fortified buildings like the bunkers in the Camargue, whose roofs are concrete slabs 15 cm thick. Some, located within woodlands are occupied by bats while others, in an open environment, are not . Plant cover, which keeps them cool during the hot hours of the one part, and the ability to keep the heat in for longer, is a favourable factor in the quality of these constructions.

The elements that determine the thermal inertia of a house, *ie* its ability to store and release heat, are : building orientation, materials, openings and surrounding landscape.

Hygrometry

Bats need a roost with a suitable humidity to avoid drying out their patagium*. In the CCAG sector occupied roosts have an **average humidity of 55% RH day and night**. Depending on external conditions, the roost can occasionally become very dry (23% RH) or very humid (84% RH), which apparently doesn't affect the presence of the animals.

Brightness

The penumbra is a comfort factor for bats, although some species such as Geoffroy's Bat can accustom themselves to a little light. Darkness is a guarantee of security in the roost as the majority of potential predators use their vision. In case of intrusion into the roost, the predator would be ineffective in pinpointing the bats. On the other hand, dark rooms deter many animals, in particular birds from occupying these buildings. Thus, pigeons or owls in need of light, do not enter the dark rooms occupied by bats. The roosts occupied by colonies were classed according to three types of darkness : complete darkness, dark, light. **The majority of roosts occupied provided at least a portion of the space in darkness, and in roost G03 had complete darkness throughout its entire volume.**

Photo 6 : Measurement of air currents with an anemometer.

Air current

Drafts were measured in roosts evaluated under action E3 (*see* photo 6). **All roosts showed a zero air flow in their volume (0 m / sec, anemometer tests) in places occupied by bats.** However, light ventilation is always present, because no mould was found and the guano dried and disintegrated.

Spaces and structures

Because they operate in three dimensions, bats need a sufficient volume. This space is particularly essential to protect them from predators on the ground, and to create a safe volume for the period when the young and training to fly within the roost. From a sample of four roosts in the Camargue and in the Gard , we noted that spaces less than 100 m³ host colonies of a maximum of 200 individuals.
Large colonies (more than 1,000 individuals) are found in roosts of more than 300 m³ (*see* Figure 5).

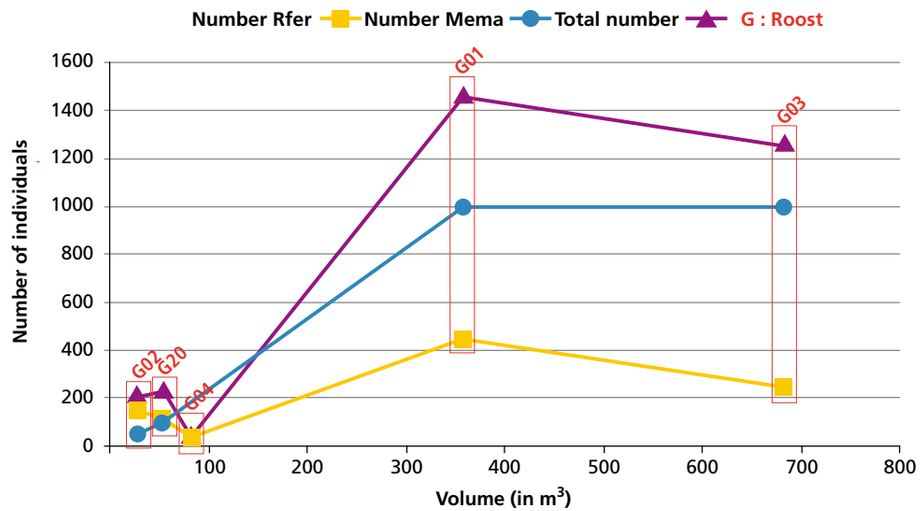


Figure 5 : Number of Greater Horseshoe Bats and Geoffroy's Bats in relation to the volume of the roosts in the Camargue-Crau-Alpilles-Gardon sector.

These large volumes also contribute to the increase in the thermal inertia of the roost. The height of the roost is without doubt also an important parameter. Spaces with a height of more than 3 m host colonies with the largest numbers (*see* Figure 6). Roost G03, which hosts a large colony in low heights seems to be an exception, however this roost has many spaces with varying heights allowing bats to move if necessary, and the threat of predation is low because there is little access for land predators.

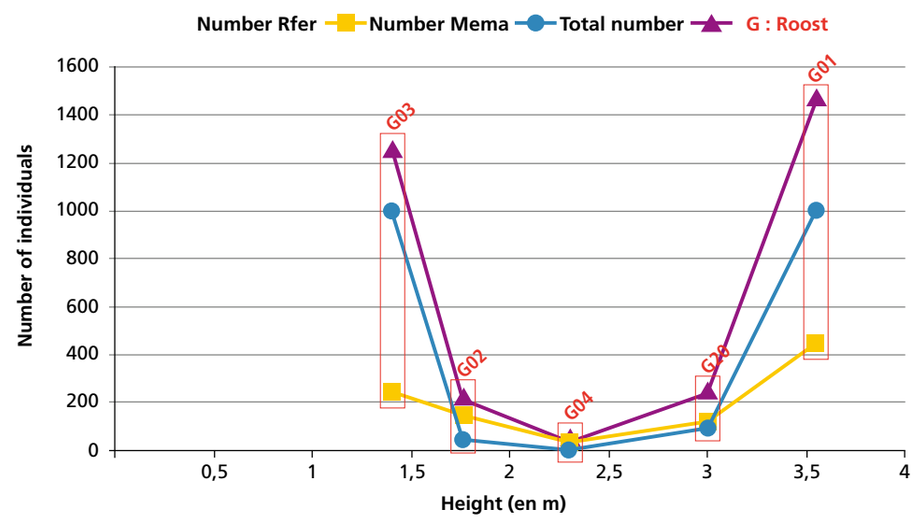


Figure 6 : Number of Greater Horseshoe Bats and Geoffroy's Bats in relation to the height of the roost in the Camargue-Crau-Alpilles-Gardon sector.

Bats choose roosts offering various spaces with a variety of micro-climates that respond to changes in their physiological requirements. Buildings divided horizontally vertically and are therefore the most favourable (*see* photo 7).

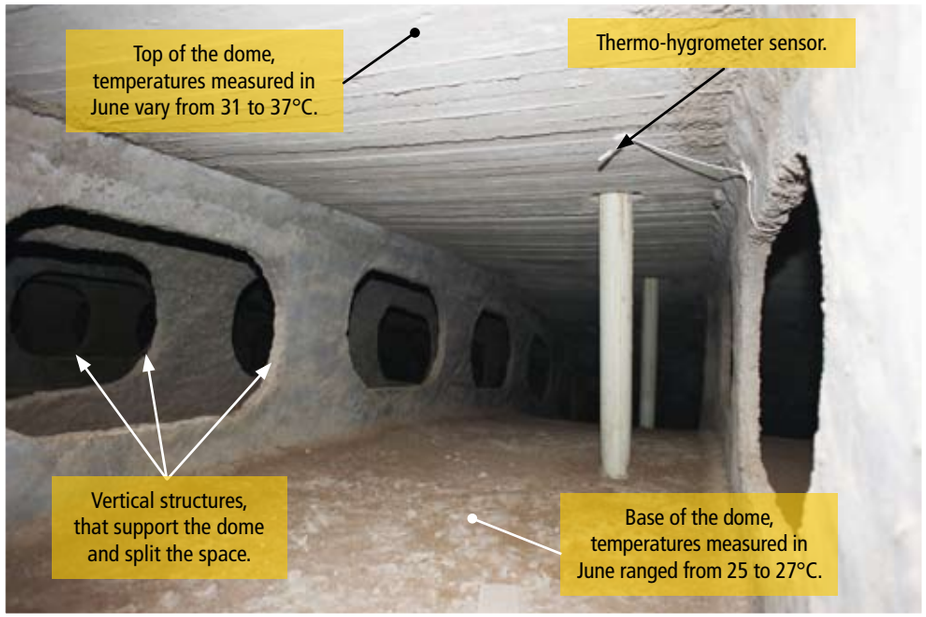


Photo 7 :Structure of the interior of the dome of roost G03. *Elements that support the dome split the space and maintain multiple thermal environments, created by insulation and air circulation. Temperatures measured on June 13, 2013 at various locations at the base of the dome and its summit are therefore very varied (gradient between 25 and 37°C).*

Evaluation of the thermic and hygrometric readings of a bat roost

Current measurement devices are powerful enough to meet the required parameters over long periods at regular time intervals. We're talking about **data-loggers*** which, fitted with specific sensor, can measure temperature, humidity, luminosity, air pressure, etc. Data-loggers nevertheless have the disadvantage of emitting ultrasound with their internal quartz and create a sound disturbance for the bats, perceptible within a few meters. It is therefore important to distinguish between two cases : roosts with bats present (case 1) and roosts without bats present (case 2).

In case 1, studied within action A2, **Micro-stations HOBO (R)** (ONSET, Bourne, Massachusetts, 170 €) with four probes were used (*see* photo 8). These probes, attached to cables of 6 to 17 m allowed the taking of readings close to the bats whilst keeping the machine, the source of noise, away from them.

In case 2, studied within action E4, data- loggers type **ibutton deviation (r)** (MAXIM Integrated Products, Sunnyvale, California, 143 €), called **Thermo-button** (measurement of temperature, 26 €) or **Hygro-button** (measurement of temperature and humidity, 111 €) were used. These small devices must be placed in the exact location where a colony installs itself (at height, on the ceiling).

- **Period of the study :** to be adapted depending on the question asked. For actions that target the general breeding period and the early arrival of spring, the optimal period is from April to September.
- **Interval of measurements :** a measurement was taken every 30 minutes for action A2 in the occupied roosts, a measurement every 2h (or 1.5h) for action E4 and in unoccupied roosts, day and night. Adaptable with regards to the available memory on the data loggers and the question asked.
- **Loading data :** with a specific USB key for the ibuttons, and the need to have its own software for each machine (ONSET and MAXIM).
- **Autonomy :** ibuttons have autonomy of 7 to 8 years in the conditions in which it was used in action E4. Micro-stations run on batteries and have an autonomy of 2 years.
- **Precautions :** to reduce emissions of ultrasound, the HOBO housing can be wrapped in cardboard. The cables for the probes can be damaged by rodents if they are numerous. Use flexible stainless steel ducts as necessary. The ibuttons are small and shiny and therefore subject to theft. Use hidden locations, or protective cages to limit the removal by small animals (*see* photo 8).

Photo 8 : Data-loggers used to characterize the roosts *(actions A2 and E4). Micro-Station HOBO with 4 sensors (to the left), a Thermo-button in place (in the middle), and a Thermo-button in a protective cage hung from a support to limit loss and theft (right).*

Openings and surroundings

Openings and access

Location / Orientation

The location of access to shelter for bats must take into account several parameters. The entry or entries should be passable by bats in flight, often in groups, but should not allow the passage of predators. Moreover, any opening that affects the internal conditions of the roost, and its effect, must be taken into account.

It is difficult to define a standard model but some recommendations can be made :

- Avoid creating a closed volume without aeration that promote mould and an unhealthy atmosphere.
- Provide, if possible, at least two openings to allow an escape for bats if necessary. This configuration also serves to create a slight ventilation and maintains a healthy atmosphere. However, avoid creating air flow in high areas (check with an anemometer).
- Orientation : openings should not face prevailing winds (cooling) or sunlight (light).
- Avoid placing openings at height, especially at the height of the roof because they prevent heat build up : hot air, trapped at height, is discharged through the openings which are too high.
- However, position the opening so as to avoid predation from outside, neither too low or close to potential perches.

Opening Size

Bats breeding in roosts studied the CCAG sector use access points 50 to 60 cm wide. This size seems suitable for a wide range of species such as the Greater Horseshoe Bat and allows the passage of a steady flow of individuals (in mixed colonies in the sector, the number varying from 40 to more than 1,000 individuals). **Openings recommended for roosts are therefore formed by a square section of a minimum of 50 x 50 cm.**

However, adaptation to the local context may be necessary. On most new roosts created for bats, adjustable openings were made, allowing its adaptation and its configuration based on the constraints.

Types of opening

The configuration of access to a roost for bats must take into account : species present and their flight characteristics, their number, threats (predators, wind, brightness) and local architectural constraints. **Several types of opening were made in under the LIFE+ Chiro Med program**, which could be adapted to each case, and tested the effectiveness of each (*see* section "The facilities put in place").

BREEDING ROOSTS : CHARACTERISTICS AND TECHNICAL ELEMENTS

Peace and security

Avoid predation

A bat roost is a place where the conditions of temperature and optimal darkness, but also **absolute tranquillity** reign. Whereas individuals seem to get used to regular sounds (noise or vibration caused by bells, traffic, etc.) that do not threaten their peace, **intrusion into their roost constitutes a major disturbance.**
In the CCAG sector, many animals may roost in buildings : owls, and especially the Barn Owl (*Tyto alba*), Mustelidae (weasel), rodents (rats, dormice) and pigeons. In addition, occasional predators such as domestic cats, rodents (rats), some raptors or corvids can notice the smooth passage of bats and post themselves near the openings to capture them. Finally, buildings are often visited by humans, which can disturb the colonies, often by negligence.

To mitigate these threats of predation or disturbance, several systems can be integrated into the features :

- Size wisely the openings and darken inside the roost to prevent the birds flying into it.
- Locate the openings at height, adapted according to the context. Note : rats can jump 1.50 m to reach an opening (predation of young bats), and cats can jump up or post themselves near an access (predation on all individuals). Attention should be paid to potential predator perches near openings (tree branches for example).
- Provide a smooth surface that covers the edges and the periphery of the opening (*see* part "The facilities put in place") and the inner walls of systems of the "tunnel". This surface prevents terrestrial predators or birds clinging on to penetrate the opening.
- Forbid human access to the building, maintain a single opening for observers when monitoring colonies, secured by padlocks.

Landscape / Environment

The immediate environment around the house contributes to the quality of its welcome. Indeed, bats, and in particular the Horseshoe Bats, protect themselves from weather and predators by flying near vegetation and artificial vertical structures when travelling. Also, before each outing at dusk, Horseshoe Bats show the behaviour of **"light sampling*"** quickly making exits and returning to the roost. They wait until it is dark enough to go hunting. **When trees are present near openings in the roost, they reduce the brightness and provide additional protection to individuals, allowing them to leave earlier for their hunting grounds and increase their intake of food.**
Moreover, the vegetation that surrounds and overlooks a roost plays a role in regulating heat, avoiding overheating in the strong sunlight in summer and slowing down the fall in temperature at night maintaining an environment saturated with hot air and protected from the wind and rain. It is possible to simulate plant protection by using special arrangements (*see* section "The facilities put in place" roost Am11).

Work on the infrastructure of the roost

Construction elements

Roof

Roofing materials are important because the roof plays a part in the heating up of the roost, and also in its ability to retain heat (thermal inertia). **Materials in earth, tiles and slates seem the most favourable since 9 occupied building roosts, from the 12 known of in the CCAG sector, have tile roofs** (with or without artificial corrugated roofing). Three of them are equipped with traditional coverage : the roofs made of **"parefeuilles"** traditional local material (*see* photo 4 on page 14) laid onto the rafters under the corrugated roofing or tiles. Other occupied roosts (G02, G03 and G06) have roofs that are concrete or stone.

Walls

All the occupied roosts that LIFE+ Chiro Med are concerned with have of stone or concrete walls (in the case of bunkers). Dense and solid materials such as stones, bricks or concrete have a high thermal inertia which might play a role in the regulation of the temperature within the roosts.
Besides the thermal role of the wall, the internal vertical and horizontal surface of walls is important because **its roughness allows or does not allow bats to attach on to it**. For example, perfectly smooth concrete or painted walls do not allow bats to hang on and techniques must then be used to create grip in these areas.

Materials to use or avoid

The choice of wood used for the structural elements such as partitions or panels for various purposes, should be subject to special precautions. Indeed **wood treatments can poison bats and even cause death** (Gremillet & Boireau 2004). Materials employed should preferably be local and appropriate for use (Class 2, 3 or 4). If necessary, alternative treatments exist (Pavisse 2012).

Photo 9 : *One Geoffroy's Bat trapped in a "Chicken coop" type fence.*

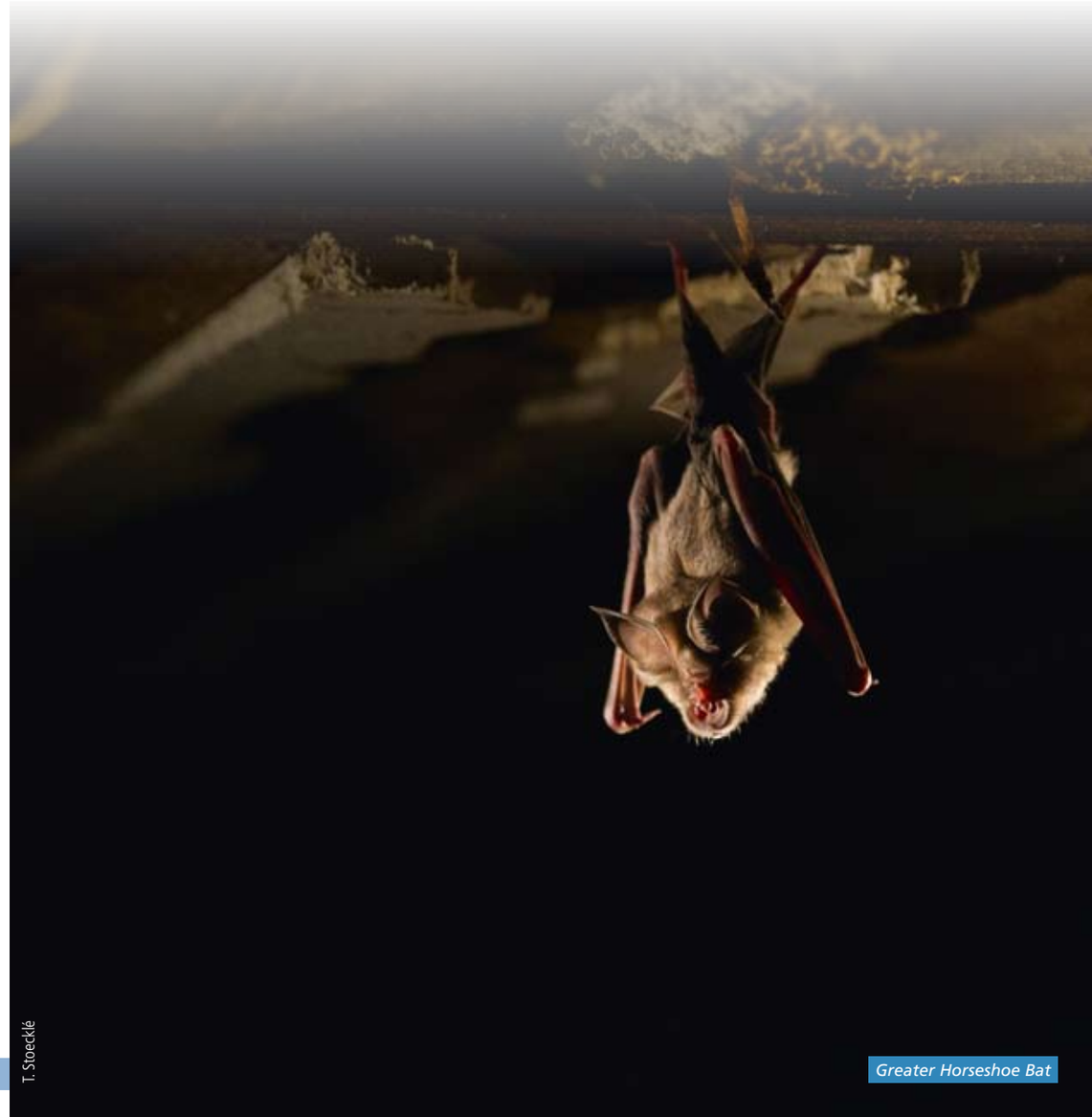
Bats are in contact with the walls of their roost, and certain materials and substances may harm them. For example, the *Minium* **(lead oxide) contained in antifouling paints is highly toxic** and the paint residues can be ingested by animals when they groom themselves, this can decimate colonies (Gremillet & Boireau 2004). Careful stripping is necessary to avoid poisoning.

In addition, precautions must be taken with any development requiring fencing or wire supports (wire, cables). Indeed, bats are highly mobile within the roost and its surroundings, and the morphology of their wings sometimes prevents them from extricating themselves from some meshes they use as support. T**he "chicken coop" style fences are absolutely prohibited** because individuals are often found injured or dead in them (*see* photo 9). A sheathed flexible mesh with small squares of 1x1 cm seems to be harmless. Additionally, horseshoe bats have been found entangled in iron or thin cables hanging from the ceiling.

BREEDING ROOSTS : CHARACTERISTICS AND TECHNICAL ELEMENTS

Schedule

Where facilities are to be provided at a roost that is already occupied by a colony, work must be completed outside the period where the bats are present. For this, it is necessary to follow the colony for a full year before planning the work, to understand when the bats occupy the roost.



T. Stoeckle

Greater Horseshoe Bat

Under the LIFE+ Chiro Med program, development work has helped sustain roosts that are already occupied by a colony (C1) and conversion of existing buildings has created new roosts favourable to host colonies of Greater Horseshoe Bats and Geoffrey's Bats (C2).

PREAMBLE

It is the bats who determine the quality of a roost. The developer has the tools to create a favourable roost, but to increase the chances of the installation of a colony, it is preferable to **design a range of sites with various conditions within the roost, offering a variety of microclimates in order that bats find, during every timeframe and every season, a place that corresponds best to their needs.**

Prerequisite : the preliminary diagnosis of the roost

While there is some consistency in the rules of construction of a bat roost, the local context often dictates the way forward. An initial inventory should gather the following :

- Exact location of the roost (geographical coordinates) and contact with the owners to get to know the area and the activities that go on around and within the roost.
- Aspect of the roost : make a catalogue of photos of all exterior and interior surfaces, including the roof. Note materials used, the insulators, and in particular the different components of the roofing (covering, insulation).
- State of the roost : identify damaged elements in the building, check for leaks, note holes and cracks in roofs and walls.
- Plan of the roost : make a sketch and add all the partitions, the vertical levels, dimensions (including height) of parts and components , the openings (access available for animals and bats). It is possible to draw these plans with 3D software (*eg*. Sketchup, freeware).
- Surrounding environment : identify and describe the vegetation adjoining the roost to a radius of 50 m. Identify woody structures (corridors). Identify sources of light, especially lighting towards the roost. Identify threats and opportunities for disturbance, actual or potential.
- Use by bats : look for clues of use (guano, insect residues). If a colony is present, observe the twilight exit to find out which access is used.
- The intrinsic characteristics of the roost : temperatures in spring and summer (day and night) light, humidity, air currents.
- Future of the building : have an exchange with the owners, evaluate the context of the use of the building, introduce bats and suggest possible conventions, estimate changes in the building in the short and medium term. Suggest a conservation plan for the colony long term.

Internal environments

Influence the thermal conditions

Under the LIFE+ Chiro Med program, existing buildings have been redesigned to make them favourable to both species concerned, essentially by passive techniques (no heating system). Internal temperature conditions can be changed by using insulators, placed in a manner appropriate to the configuration of the roost and according to the desired thermal effects. **The isolation of certain walls** or roof panels, with cork or hemp for example, **allows the maintenance of heat** in certain areas (*see* photo 10).
Conversely, non-insulated surfaces will allow heating or cooling of a volume.

Photo 10 : *Isolation of part of a wall with cork (roost Am09).*

Photo 11 : *Development of a bunker* ***(roost Am11).*** *This painted black door is equipped with a padlock allowing passage to observers.*

It is possible to **heat a space by using metal surfaces painted black** (*see* photo 11) or non insulated surfaces oriented in such a fashion that they attract the rays of the sun. In the case of a low-rise building, it is possible to insulate the roof from the outside using straw bales, this helps regulate heat within the roost. This arrangement, in addition to the presence of Giant Cane, simulates protection (against the wind and rain) that could be provided by local woodland. Keep a portion of the roof exposed, facing south, which will heat the interior space, the hot air is then trapped in the isolated space

Create an internal structure

In order to increase the surface roughness, it can be covered with a metal screen, on the ceiling and the upper part of the walls (at a height of about 50 cm, *see* photo 12) or battens of wood can be regularly arranged on the ceiling.

Photo 12 : *Metal screen to facilitate the attachment of bats on ceiling and upper walls (roost Am09).*

The use of wood panels or fabric drapery creates **adjustable divisions** to limit the brightness in the house, creates different thermal environments and cuts drafts (*see* photos 13 and 14).

Photo 13 : *Tunnel guiding bats into the attic of roost G07. The device reduces the brightness and current of air.*

Photo 14 : *Partition between two parts of the roost Am05. A modular opening allows the passage of bats and observers from one room to another.*

Tall buildings offer the opportunity to develop **on different levels, and thus create volumes with various conditions (*see* photo 15)** : the cool places can be used between seasons by individuals in lethargy, and the hotter places can accommodate females in gestation and lactation.

Photo 15 : *Old transformer developed over two levels for Greater Horseshoe Bats and Geoffrey's Bats (roost Am10). A passage is provided for bats fitted with a ladder for observers.*

Openings and access

Simple openings letter box type (roost Am13)

Objectives : to provide easy access for the Greater Horseshoe Bat and Geoffroy's Bat to a door or a wall, but restrict the entry of unwanted animals (mammals, birds, *see* photo 16).

Dimensions : 48 x 10 cm

Features : the opening is covered in zinc on its lower and vertical edges to avoid other animals (especially birds) clinging to it and entering. The advantage of this opening is its ease of implementation, especially in a door, which can be conserved for the passage of observers. The downside is the size of a small opening prevents the passage of several bats at a time.

Photo 16 : *Bat's door "letter box" at roost Am13.*

Adjustable chicanes (roost Am11)

Objectives : make barriers using structures that create chicanes. Provide easy access for Greater Horseshoe Bats and Geoffroy's Bats cut in to a door, which restricts entry of wildlife, darkens the room, limits air currents (*see* photo 17 and Figure 7).

Dimensions : dimensions are adapted according to the species. the width is between 40 and 50 cm. For the Greater Horseshoe Bats, the height is 20 cm minimum throughout the flight path (chicane included).

Features : the opening is protected by an outer panel and bats must pass under this panel that creates a vertical chicane (*see* Figure 7). The difficulty of the passage through the chicane is adjustable by moving the outer panel height and depth. This type of passage is not ideal for a large influx of bats. A panel can also be positioned inside to create a lateral chicane (*see* photo 17) to guide bats to a side opening, which deters birds from flying in by creating a barrier and lack of visibility. In this case, the edge of the opening is protected by zinc to prevent birds and terrestrial predators clinging on.

Photo 17 : *Lateral chicane consists of a partition which guides bats to a room on the right side (roost Am11).*

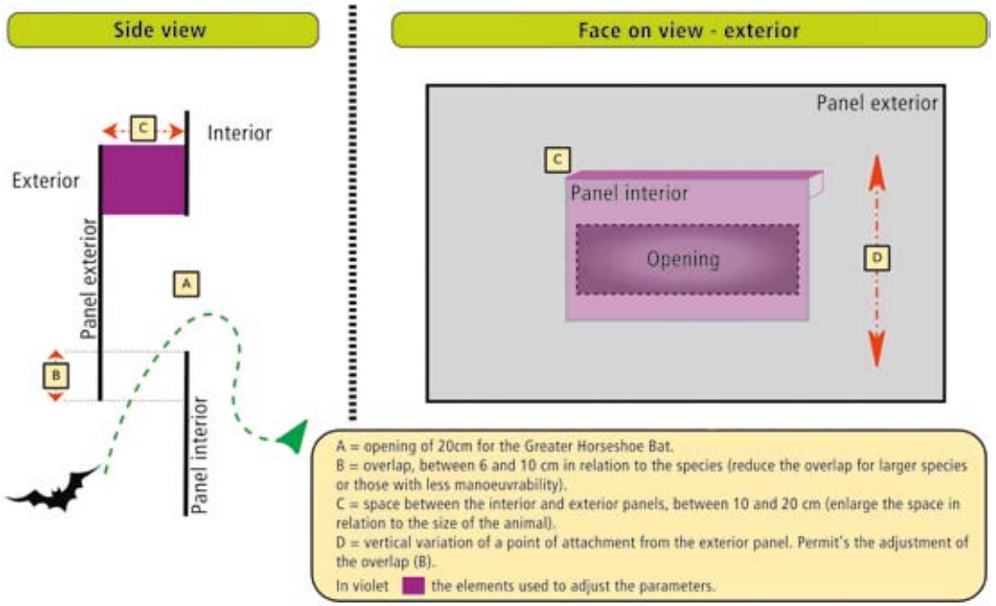


Figure 7 : *Details of a adjustable bat chicane. The difficulty of the passage of the chicane is adjustable in height (B) and depth (C).*

Hatch (roost G04)

Objectives : to provide easy access to Greater Horseshoe Bats and Geoffroy's Bats at height on a pinion, limiting the entry of unwanted animals, darkening the room and limiting air currents (*see* photo 18 and Figure 8).

Dimensions : the opening is a square of 50 cm each side. The slope of the hatch is about 45°, avoiding as far as possible the creation of horizontal portions.

Features : the hatch is coated on its inner surface with a smooth surface so grip is not possible, which prevents the intrusion of predators. In the case of roost G04, it is also through this hatch observers enter to monitor the colony, sliding it up by the handles (requires safety pegs on the exterior of the pinion).
This type of opening allows the steady stream of passage important to bats.

Photo 18 : *Hatch permitting access for bats to the attic (roost G04).*

PUTTING IN PLACE THE FACILITIES

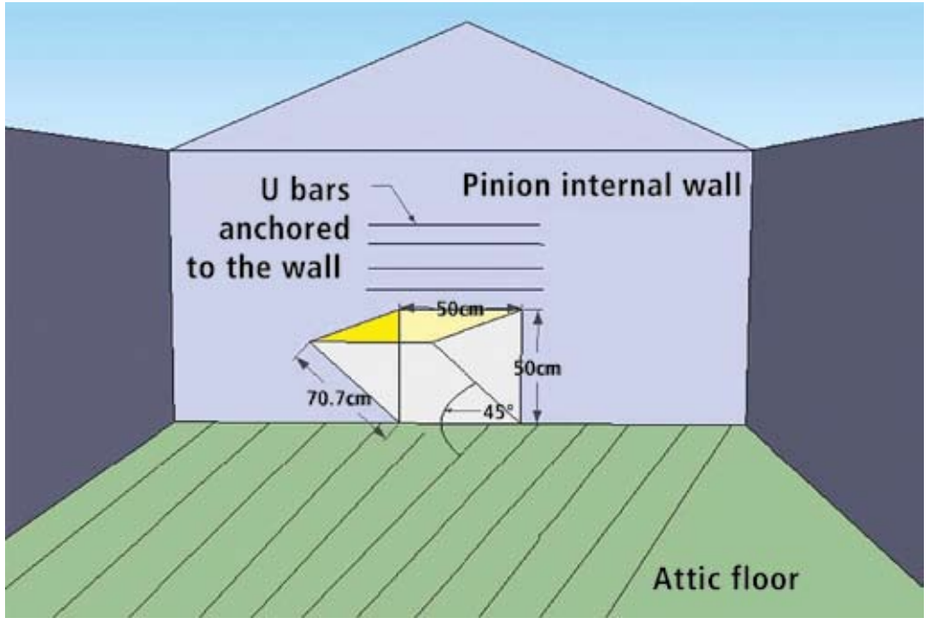


Figure 8 : *Details of hatch inclined at 45° allowing access to the attic by bats.*

Funnel (roost G03)

Objectives : to provide easy access to Greater Horseshoe Bats and Geoffroy's Bats to the upright, to limit the entry of unwanted wildlife and to guide bats safely to a suitable volume (*see* Figure 9).

Dimensions : the opening is a square of 50 cm each side. The inclination of the sides, of approximately 40°, can be adapted locally according to the space available. The tunnel length is 50 cm. A system for varying the inclination of the panels can be installed to adjust the difficulty of passage and increase the efficiency of the funnel.

Features : the funnel is covered on the inside with a smooth surface making attachment impossible, which prevents the intrusion of unwanted wildlife. Inside the roost, the tunnel avoids a potential predator positioning itself at the edge of the opening to capture passing bats. This type of opening allows the passage of a large and regular stream of bats.

Whatever model of opening used, it is important to maintain a volume of free space of 1 m³ at the entry into the roost, in 3 dimensions, so that bats can manoeuvre and brake before taking hold.

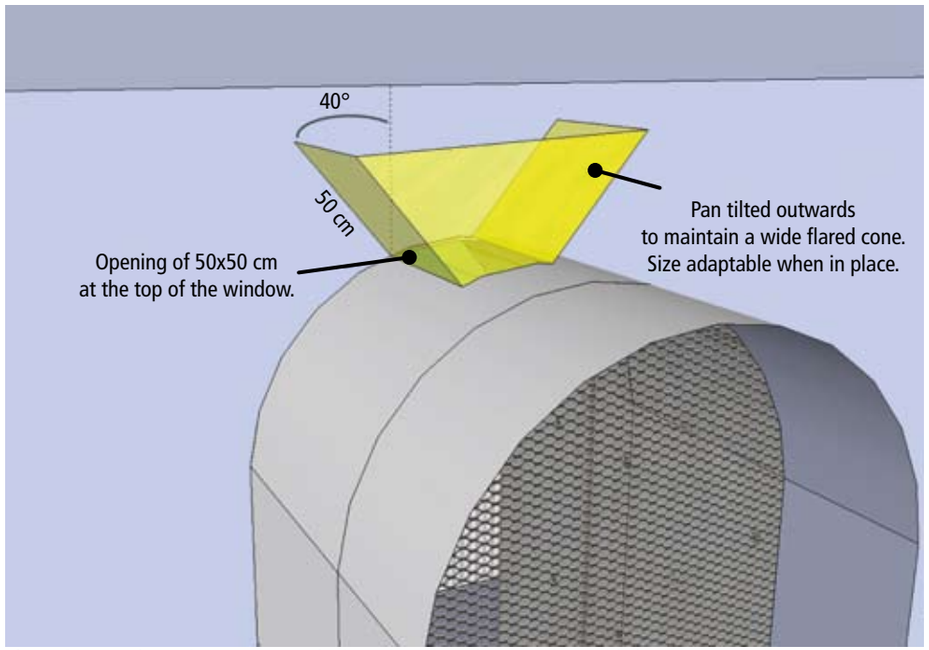


Figure 9 : *Funnel opening to prevent the intrusion of predators and to guide bats.*

Geoffroy's Bat.

Assessment of facilities and sustainability of roosts

Monitoring of heat and humidity

The efficiency of improvements must be tested to verify that the roost actually provides conditions favourable to the installation of bats. **Monitoring the temperature and humidity must be committed to over a period corresponding to the intended use of the roost, before and after the work.** For a breeding roost, monitoring will be conducted between April and September (E4) to confirm that the house does not overheat in the summer, and that it offers temperatures that are high and stable in the spring.

This monitoring is used to check the effect of the development on the conditions in the roost and to consider any adjustment by changing the openings, insulators, and structures or materials. **The modular access systems are particularly important** in the case of a complex building.

Occupation by bats

The installation over time

A roost developed for bats, although favourable, is not colonized immediately. It is during their daily explorations that individuals discover potential new shelters, and if they are favourable, they settled there. **Experiments show that several years may be necessary.**

On the Porquerolles' island, a breeding colony of Geoffroy's Bats moved in permanently five years after the construction of a roost specially created for them, near an existing colony.

In Brittany (GMB study, Groupe Mammologique Breton *in french*), Greater Horseshoe Bats used a roost almost immediately after its construction (1 individual) year N.
Progressive use by individuals then follows until there is an effective colonisation :
- Year N+5 : a group of more than 100 individuals moved in during spring transit.
- Year N+5 : a breeding colony of 50 individuals moved in during the summer.
- Year N+6 : a breeding colony of 100 individuals is present.
- Year N+7 : a group of 150 individuals use the roost for hibernation.

In the case of development of a roost that is already occupied, the acclimation time is reduced, and bats often settle the year following the development (provided that the conditions are favourable).

Attract bats to a new roost ?

The question may arise about how to increase the chances of colonization by bats. Two areas have been explored in recent years : the recognition that individuals have between them, through smell, and by their other acoustic signature. Recent studies have thus shown :

- That individuals of the same species tend **to come closer if they recognize the smell** of their colony (olfactory signature of the group, Bloss *et al.* 2002).
- That Horseshoe Bats can **distinguish the sex of another individual from cries issued**.
- There are **various types of social calls which have specific functions** (Pfalzer & Kusch 2003).

On the other hand **the social calls**, hich seem to have an intricate communication function, **are sometimes used as an acoustic decoy** to attract bats into the nets during catches or in roosts (Chaverri & Gillam 2010, Goiti *et al.* 2007, Hill & Greenaway 2005, Pfalzer & Kusch 2003, Schöner *et al.* 2010, Spanjer 2006, Russ *et al.*1998). However this area is still little understood and **seems to cause problems for the local population**, particularly disturbing animals by issuing cries that are perceived as aggressive. If acoustic lures are used in the wild with care, the method deserves nevertheless to be developed to attract animals to an unknown roost (Chaverri & Gillam 2010).

With the perspective gained following improvements made through the LIFE+ Chiro Med program two attraction techniques are considered. Firstly, Greater Horseshoe Bat guano will be dispersed in the new roosts created to include a familiar scent. Then a technique of attraction through social calls can be experimented with. Current knowledge suggests that certain types of calls are for communication between individuals and not aggressive interactions. It therefore seems preferable to use these specific cries, or a general soundscape of a breeding colony, to test the effect on the new roost.

Signs of the presence of bats

Following the occupation of a roost by bats, whatever the time or the number of individuals, is a good indicator of the quality of the roost. **Visits may be made four times year** to coincide with each major life stage : reproduction (July) hibernation (January-February), spring transit (April) and autumn transit (October- November). At each visit, the presence of bats or evidence of their presence (guano, insect remains) are noted. It is also possible to develop monitoring protocols using modern tools such as automatic ultrasonic detectors or infrared automatic cameras (*see* Technical Guide No. 6 "Imaging techniques in the service of conservation").

Long-term monitoring of populations

A breeding colony housed in a roost returns each year, as long as the roost is favourable. Monitoring of the colony permit's the evaluation of female reproductive success, survival of the young in their first few weeks, and to participate in large-scale monitoring of populations. It also helps to identify potential problems (predation, degradation, etc.). Three checks per year allows the collection of information under the important parameters (*see* table 3).

Tarpaulins can be installed under the colonies to recover the guano. This prevents an excessive accumulation, and this natural and effective fertilizer can be reused.

Table 3 : Details of population monitoring for a breeding colony.

Time of inspection	Parameters
Monitoring 1 : just before the first Parturition (P)	Maximum number of adults before parturition + roost temperature + + eventual mortality
Monitoring 2 : P + 10 days	Number of adults + number of youngs + eventual mortality
Monitoring 3 : P + 30 days	Number of adults + number of youngs + number of youngs ready to fly + eventual mortality

PUTTING IN PLACE THE FACILITIES

Communicate and sustain

If the developed roost is secure and regularly monitored, and if its tranquillity is unlikely to be disturbed by increased human use, **it is possible to install an informative sign explaining the action** nearby (*see* photo 19). During the development work in the course of actions C1 and C2, **12 panels were prepared** to present the context of the development and to introduce the rare species present.
The sustainability of a bat roost is essentially guaranteed by the accession of owners to the cause. It is therefore important, in addition to a monitoring and preservation agreement to establish **regular exchanges in order to engage the various stakeholders** and share knowledge of the site. From a global point of view and according to local wishes, **a "network of owners" can be created and animated locally**, or integrated into the national shelter operation (www.sfepm.org/refugepourleschauvessouris.htm). Each Regional Bat Group (GC) guides the local implementation of the operation "Shelters for bats", the GCP in PACA and the GCLR in the Languedoc -Roussillon. **All colonies initially targeted by LIFE+ Chiro Med are subject to an agreement** between the owner and / or site manager, territorial manager (PNRC, AMV, CDL, SMGG, SMCG) and a group of local naturalists (GCLR, GCP). These agreements indicate the presence of bats, connect with partners for joint conservation of colonies, and manage the arrangements for monitoring populations and the exchange between signatories. If the preservation of a colony on a site can sometimes be in confrontation with local activities, to integrate them, and raise straight away any reticence, many owners have known "their" colony for a long time and show much cooperation in the process of collective monitoring.

Photo 19 : *Information panel for roost AM01, showing changes made by the development of the roost and the target species.*

Feedback from a finished development

Example of roost AM09 north of Vaccarès

Initial state of the site Am09 (E4)

The building Am09 is a small building serving as an agricultural shelter, with a volume of 40 m³ and a minimum height of 2 m, on one level. Not being in use, traces of decay were visible and a roof leak was present (*see* photo 20). This site was not used by bats despite some access points and was chosen as a building to convert. The presence of two rooms permitted the creation of two different atmospheres (*see* photo 21). The main room (room 1) is characterized by a mean summer temperature in the comfort range, reaching a maximum of, but no greater than 30°C. The small room (part 2) had a certain freshness in the spring and a comfortable average in the summer. Both rooms however could reach minimum temperatures below the comfort range.

Photo 20 : *Exterior view of roost Am09 before development.*

Photo 21 : *Interior view of roost Am09 before development.*

Development of roost Am09 (C2)

Following the characterization of the roost, the following actions were carried out in late January 2012 :

- Repairing various cracks to deal with leaks in the roof terrace.
- Replacing the existing door and securing it with a padlock.
- Development of a bat's door type "adjustable chicane" on the door (*see* photo 22).
- Insulation of all walls and ceiling with panels of hemp and cork, and doubling with panels of plywood to improve the thermal inertia of the building (*see* photo 23).
- Installation of metal screens on the ceiling to facilitate the attachment of bats (*see* photo 12 page 26).

Photo 22 : *Bat's door type "adjustable chicane".*

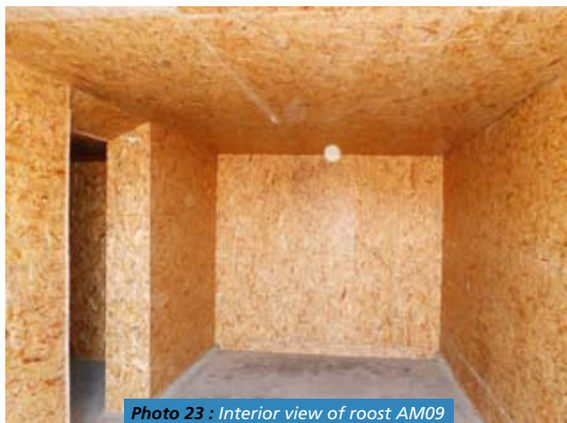


Photo 23 : *Interior view of roost AM09 after development.*

Evaluation of the effectiveness of development (E4)

The comparison of the characteristics of the roost before and after development to check their effectiveness. The developments have reduced the maximum temperatures of room 1 without significantly changing modify those of room 2 (*see* Figures 10, 11 and 12). Furthermore, minimum temperatures in room 2 were slightly increased. However in spring and summer periods, the house as a whole was less hot than before because it had no significant aeration (intake of hot air insufficient), is only on one level and lacks the structure which permits heating by concentrating the suns rays and therefore the transfer of heat.

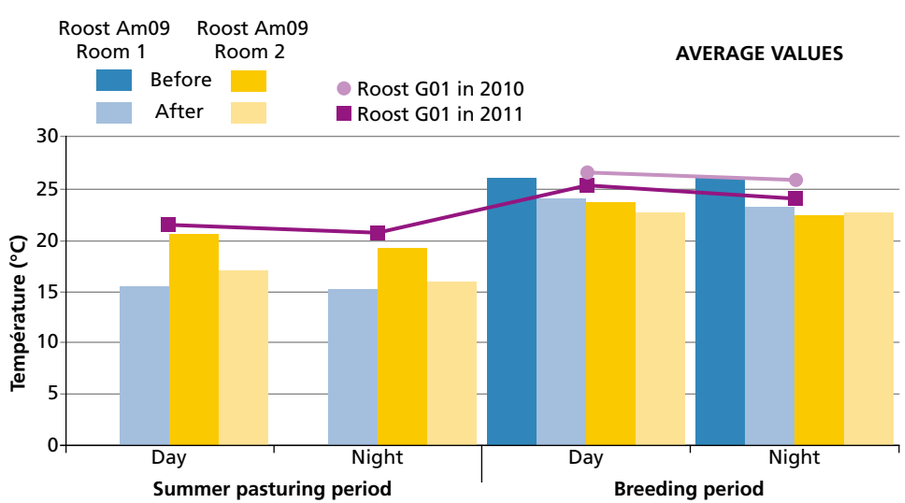


Figure 10 : *Measurements of average temperatures in the two roomss of the house before and after development of roost Am09. Data relating to roost G01 serve as a reference, this roost is occupied by bats.*

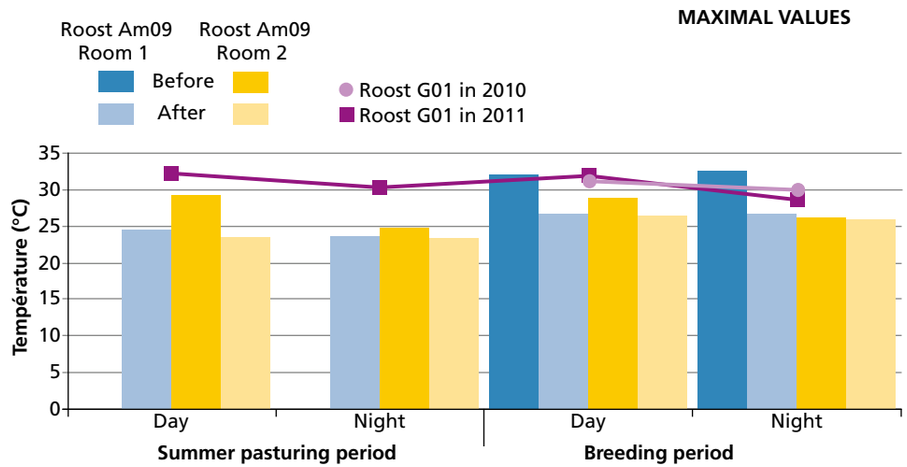


Figure 11 : *Measurement of the maximum temperatures in the two rooms of the roost Am09 before and after the development. Data relating to roost G01 serves as a reference, this roost is occupied by bats.*

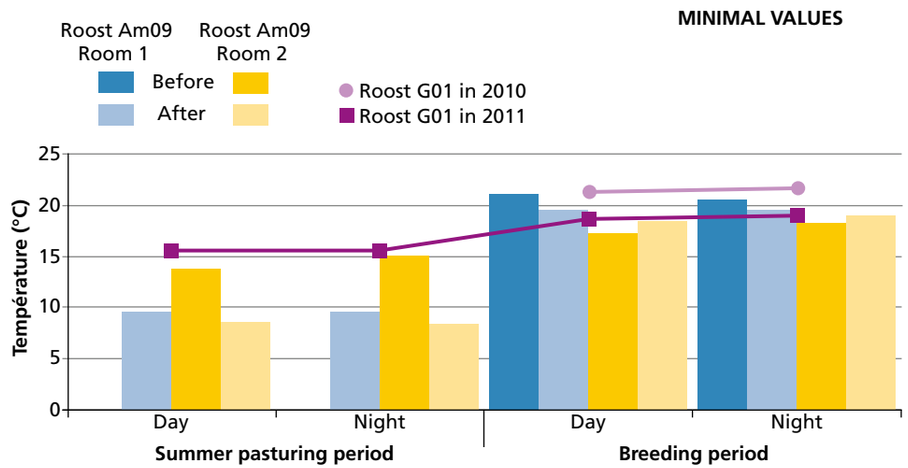


Figure 12 : *Measurement of minimum temperatures in the two rooms of the roost AM09 before and after the development. Data relating to roost G01 serves as a reference, this roost is occupied by bats.*

Prospects for improvement

To increase the heat in the roost early in the season, improvements have already already been commenced, while continuing with the temperature monitoring. The size of the opening in the door will be slightly increased and a light air flow created by a further opening on the opposite side to allow the hot air to penetrate and ventilate the building. Furthermore, a part of the insulation on the ceiling and metal door may be reduced to create a surface that attracts sunlight and heats the inside of the roost from spring onwards.

This case demonstrates the need for an assessment post development, which can lead to changes in the work completed. Wherever possible, the placement of adjustable elements is desirable. It is also possible to simulate adjustments with light materials and temporary facilities, which, once tested, will help develop the final facilities.

Implementation costs

Implementation costs for a single development on a site with a small surface area such as roost Am09 are given by way of example (*see* table 4).

Table 4 : Figures for the development of roost Am09.

Task	Price in € (inc VAT)
Waterproofing roof: Patching cracks and repointing to sealing the roof, an area of 19.5 m².	7 347,76
Replacing the existing door with a metal door (about 1.26 x1.90 m) padlocked, equipped with an access hole and with chicane, and insulation with panels of hemp 6 cm thick.	
Mounting a frame on the ceiling rafters 5 x 7 and brackets for attaching the hemp insulation panels 6 cm thick, for all the walls to be covered with plywood 12 mm thick to buffer temperature variations. Blocking of the openings to the exterior with plastered brick (6 units) : • 3 openings 0.17 m in diameter. • 1 opening of 0.27 m in diameter. • 1 opening of 0.30 m in diameter. • 1 opening 0.50 x 0.58 m.	
Metal sheet 2 x 2 mm mesh.	363,00
Wooden battens to strengthen the attachment of the mesh.	75,99
Changing the dimension of the bat' door.	Realization internally
Recording thermometers (price per thermometer).	70, 60
Consumables for thermal buttons protection.	3,14
OTAL in € (inc VAT)	**7 860,49**

CONCLUSION

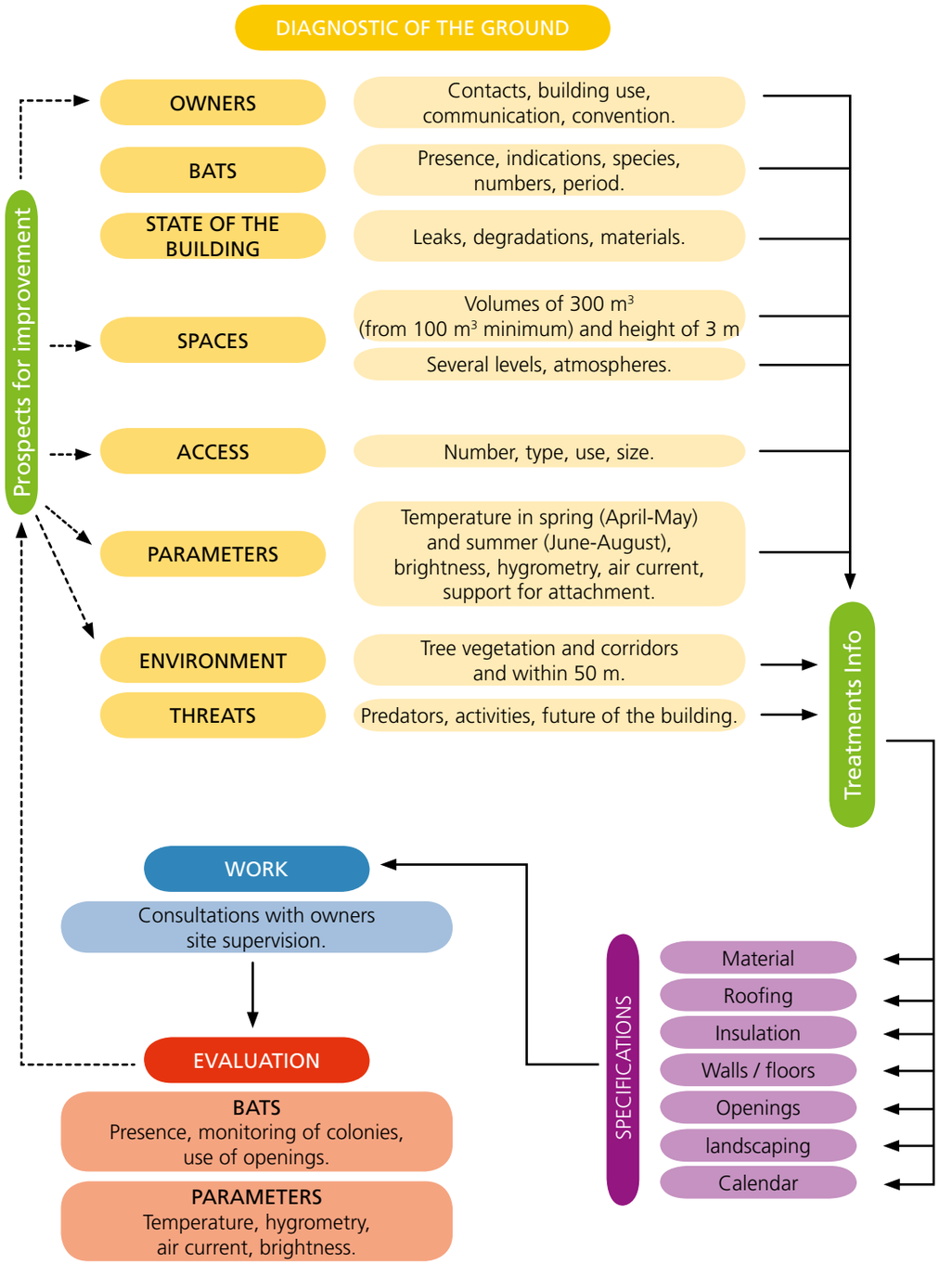
One of the objectives of the LIFE+ Chiro Med program was to protect and maintain a network of roosts in the Camargue area. This collective goal has now been achieved in the Camargue-Crau-Alpilles-Gardon sector and a dynamic watches over this network, as well as monitoring the population that uses it.

Several technical guides exist on the subject of development of roosts for bats. Under the LIFE+ Chiro Med program, a specific protocol was established to adapt to the local context, researching occupied roosts for the attractive qualities for bats during the breeding season. The synthesis of these locally tailored specifications at each building and for each climate has led to the identification of strategies to improve existing, or to build new roosts. This knowledge and the acquired technical and methodological skills are today transferable not only around the Mediterranean, but also elsewhere in Europe, where the Greater Horseshoe Bat anf Geoffroy's Bat seem to have the same basic needs.

Developments, often simple and evolutionary, help rehabilitate buildings without a current purpose, and establish a real and lasting foundation for the long- term population of the bat. The creation of new roosts to meet the requirements of bats strengthens the network of sites necessary for the fulfilment of their life cycle, and thus averts a possible rapid degradation of their environment.

K. Lombardini

Overall approach used for the construction of a breeding roost for the Greater Horseshoe Bat and Geoffroy's Bat in the Camargue–Crau–Alpilles–Gardon sector.



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...

CCAG Sector : sector of concern for the LIFE+ Chiro Med program and formed by the Camargue delta in the broad sense (Camargue Provence Gard), the Crau, the Alpilles and Gardon gorges. It is at this level that the conservation of the two species is discussed.

Data loggers : literally "loggers of data" are electronic programmable devices capable of recording measurements over long periods. The data loggers contain a quartz whose ability to oscillate at a constant frequency is used to mark the measurement of time. This quartz emits ultrasound incompatible with the presence of bats.

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).

Epigenetic : organism or element at the surface of the earth, above the ground.

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.

Fissuricole : Propensity of certain animal and plant species to live in cracks and crevasses, usually present in rock areas or trees.

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.

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.

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.

Hygrometry : measurement of humidity. Relative Humidity, RH denoted, which is the percentage of the maximum value of humidity in the air at a specific temperature.

Hypogeous : organism or element located below the ground level.

Life cycle (= vital cycle) : succession of phenomena constituting the stages in the life of a animal or plant species. The life cycle of bats is detailed on page 3.

Light-sampling : behaviour of some bats who go out and immediately back in to the roost several times before going hunting at dusk. This behaviour is interpreted as a means of assessing the brightness outside, and waiting for the appropriate moment to go hunting safely in the dark.

Micro-roosts : term used to designate a small roost, as opposed to roosts of large volume in constructions (roofs, for example) or caves. The micro-roosts are usually small cavities in trees or rocks. It is commonly considered that if the opening size is smaller than that of Black Woodpecker *Dryocopus martius* the cavity is a micro-roost.

Parefeuille : rectangular terracotta tile, used for flooring or roofing under other tiles.

Patagium : membrane of skin connecting members (wings) and the tail in bats, allowing flight.

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).

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.

Thermal dephasing : lag in heat transfer from the direct external insulation to an interior space of a specific building. This shift can prevent the an accumulation of solar energy during the day (overheating) by slowing down the temperature rise, and can trap this heat for a good part of the night by slowing down cooling.

Thermal Inertia : thermal inertia is the ability of a material to resist changes in external temperature. In a building, it is directly related to solar radiation and ventilation : it can store the energy received by the building and return it slowly when necessary, or to evacuate it by night-time ventilation. The inertia allows the regulation of the thermal environment within a building, and thereby enhance the thermal comfort (source : archi.climatic.free.fr/inertie.html).

Thermoregulation : physiological mechanism for regulating the temperature of the body in warm blooded animals (at a constant temperature) such as birds and mammals.

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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Editions LIFE+ Chiro Med
www.lifechiromed.fr

General Coordination
Véronique Hénoux et Katia Lombardini
Parc naturel régional de Camargue (PNRC)
www.parc-camargue.fr

Editing
Delphine Quekenborn et Emmanuel Cosson
Groupe Chiroptères de Provence (GCP)
www.gcprovence.org

Véronique Hénoux
(PNRC)

Proof readers
Damien Cohez ***(Tour du Valat)***
Géraldine Kapfer ***(GCP)***
Katia Lombardini ***(PNRC)***

Graphic design and layout
Vincent Lemoine
lemoine_v@yahoo.fr

Translation
Sally Simmonds
sallymsimmo@hotmail.com

Illustrations
Cyril Girard
www.cyrilgirard.fr

Photo credits
Emmanuel Cosson *(photos 9, 16, 20, 21)* - ***Leila Debiesse*** *(photos 8m, 14)* - ***Christelle Galindo*** *(photo 10)*
Groupe Chiroptères de Provence *(photo 5)* - ***Corinne Guintini*** *(photo 15)* - ***Véronique Hénoux*** *(photos 6, 8d)*
Katia Lombardini *(photos 12, 13, 17, 18, 19, 22, 23)* - ***Sam Pereira*** *(photo 4)* - ***Martin Picart*** *(photo 2)*
Delphine Quekenborn *(photo 3)* -***Tanguy Stoecklé*** *(photos 1, 7, 8g)* - ***Élodie Thirion*** *(photo 1)*

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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. 1

Systems to help with the crossing of roads

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Management of bovine parasites and wildlife coprophagia

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Conducting winter surveys in cavities

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