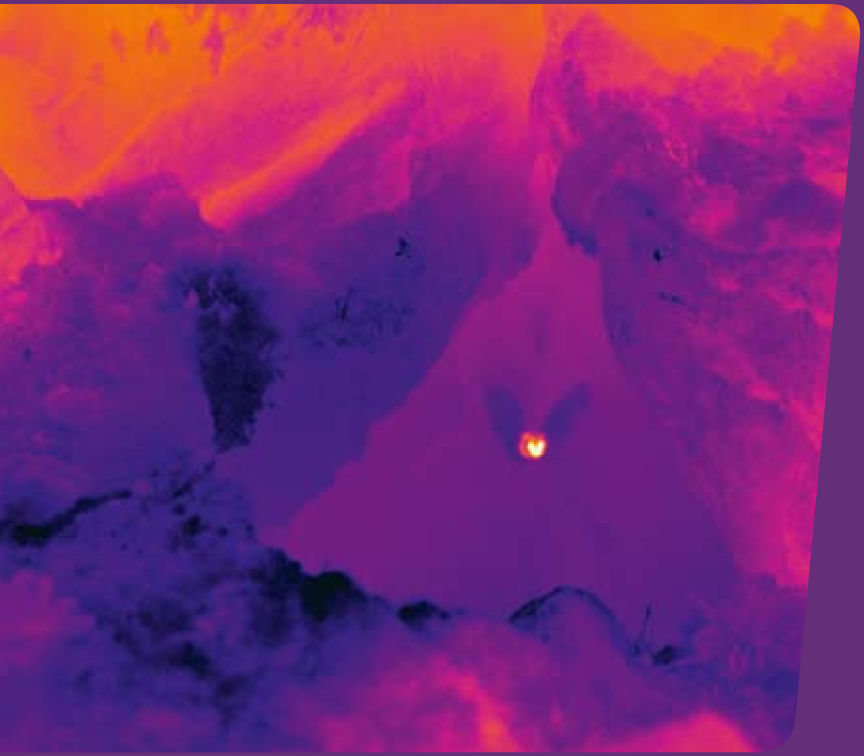
Technical Guide No. 6

Imaging techniques in the service of conservation



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

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 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.

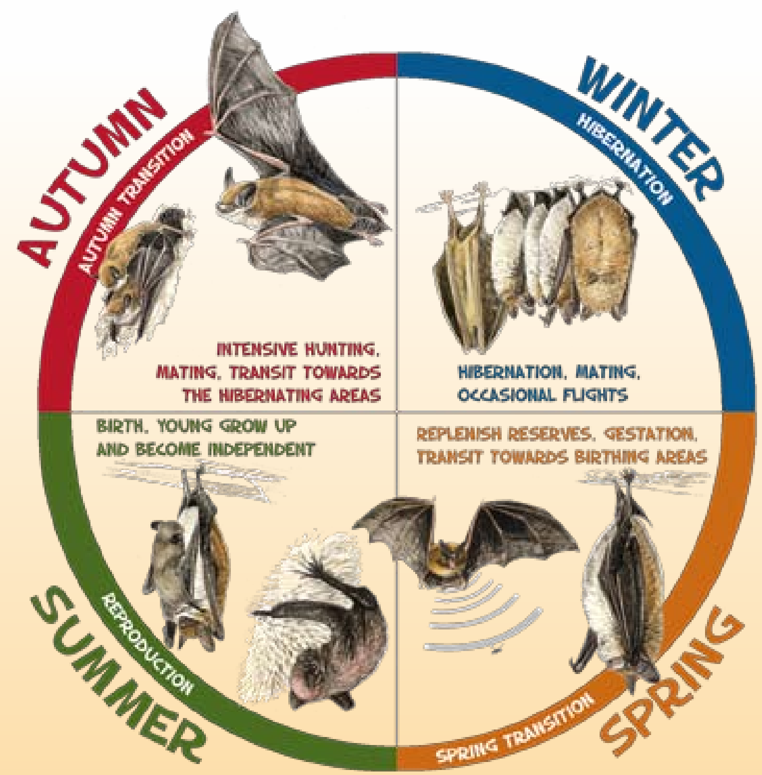
All bats are protected by law by means of :

- **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).

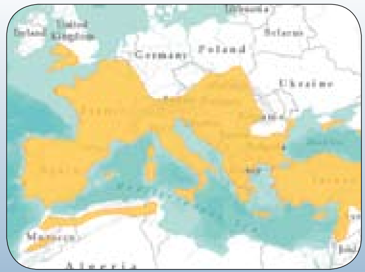
T. Stoecklé

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).

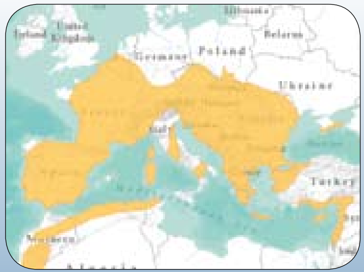
Roosts : The breeding roosts are mainly attics or lofts but can be barns, caves, or bunkers as in the Camargue, temperate (23-27°C). Females congregate in swarms of 50 to 600 individuals. Males generally pass summer alone. In winter, the species hibernates in caves, quarries, mines and large caverns 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**.

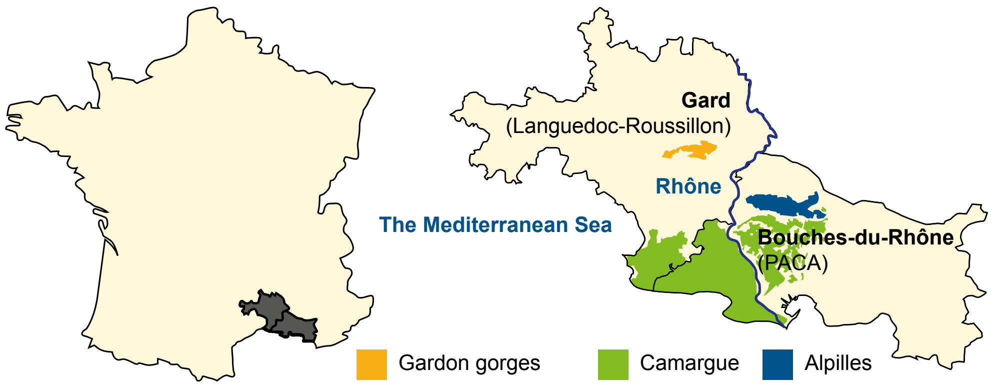


Map source : IUCN (International Union for Conservation of Nature) 2008. *Myotis emarginatus. In* : IUCN 2013. IUCN Red List of Threatened Species.

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".

BATS AND NOCTURNAL OBSERVATIONS

Bats, animals that are very difficult to observe

Some animals are easier to observe than others. Bats are among the most difficult of animals to observe and study. Indeed, their biological characteristics complicate the task of the scientist, photographer or filmmaker.

The first constraint is that they are nocturnal and shelter during the day in places immersed in darkness. If some nocturnal animals are very sensitive about having the spotlight on them for the purpose of shooting, like deer, weasels or nocturnal birds of prey, bats have such a sensitivity to light that any use of a projector of "visible light" may derail the shooting and therefore the study.
Worse still, their lucifuge* character means that, if disturbed, bats may disappear. They therefore impose on you a technique which must be ethical and flawless, or there is the threat you will see them leave their roost.

The second constraint is that their size varies between that of a wren and that of a tit. This imposes a certain proximity to the animal to get good enough footage to analyse their behaviour.

The third is their speed, because they are not only content to fly in the dark and to measure the size of a plum, they also fly at high speed, mainly in the vegetation, making it difficult to follow a sequence of flight…

In summary, a scientific cinématographique headache !

V. Hénoux

Tanguy Stoecklé on the location of the film "Life of the Greater Horseshoe Bat".

Technical specifications

Which rate of capture for which observations ?

The rate of capture is the number of frames per second, per hour or per day. The audiovisual standard in Europe is 25 frames per second (25 ips or 25 fps). This is the basis for movements to appear fluid even if 15 frames per second is sufficient to give this impression. And it is at 25 fps that most video recordings are generally made.

However, studying the biomechanical behaviour of a bat in flight does not require the same frequency of capture as images taken to study the daily movement of bats within their roosts.

In the first case, a frequency of 500 or 1,000 fps is required while in the second case, an image every half hour will be sufficient. The equipment used will be very different. But be aware that once the images are shot, all the sequences, whatever the rate of capture used, they need to be reduced to 25 fps for viewing.

Thus, a sequence of the film shot in 500 fps and which only lasts a second (a bat flying past) will finally be 20 seconds and will allow you to see, by **slow motion**, the behaviour which is totally invisible to the naked eye.

Conversely (and yet with the same final result), a sequence of photographic images taken in a breeding roost over 10 days with an capture frequency of an image every half hour will end up as a little more than 19 seconds, and will also show with **acceleration**, behaviour totally invisible to the naked eye. If this sequence is synchronized with temperature readings, some behaviours displayed by the colony in the roost can be analysed by a "temperature / behaviour" report.

The spectrum of light

The spectrum of light is part of the electromagnetic spectrum which shows the distribution of electromagnetic waves according to their wavelength, frequency or their energy.

This band of electromagnetic waves is distributed on a scale of 0.001 nm (nm 1 nm = 10-9 m) corresponding to gamma rays, 10^{+14} nm corresponding to radios waves (*see* Figure 1).

The visible spectrum is the portion of the electromagnetic spectrum that is visible to the human eye, that is to say a representation of all monochromatic components (violet, blue, green, yellow, orange and red) of the "visible light".

The human eye perceives the electromagnetic waves whose wavelengths are between 380 nm for violet and 780 nm for red.

The spectre of "visible light" for human beings is a very narrow waveband over the entire electromagnetic spectrum scale.

BATS AND NOCTURNAL OBSERVATIONS

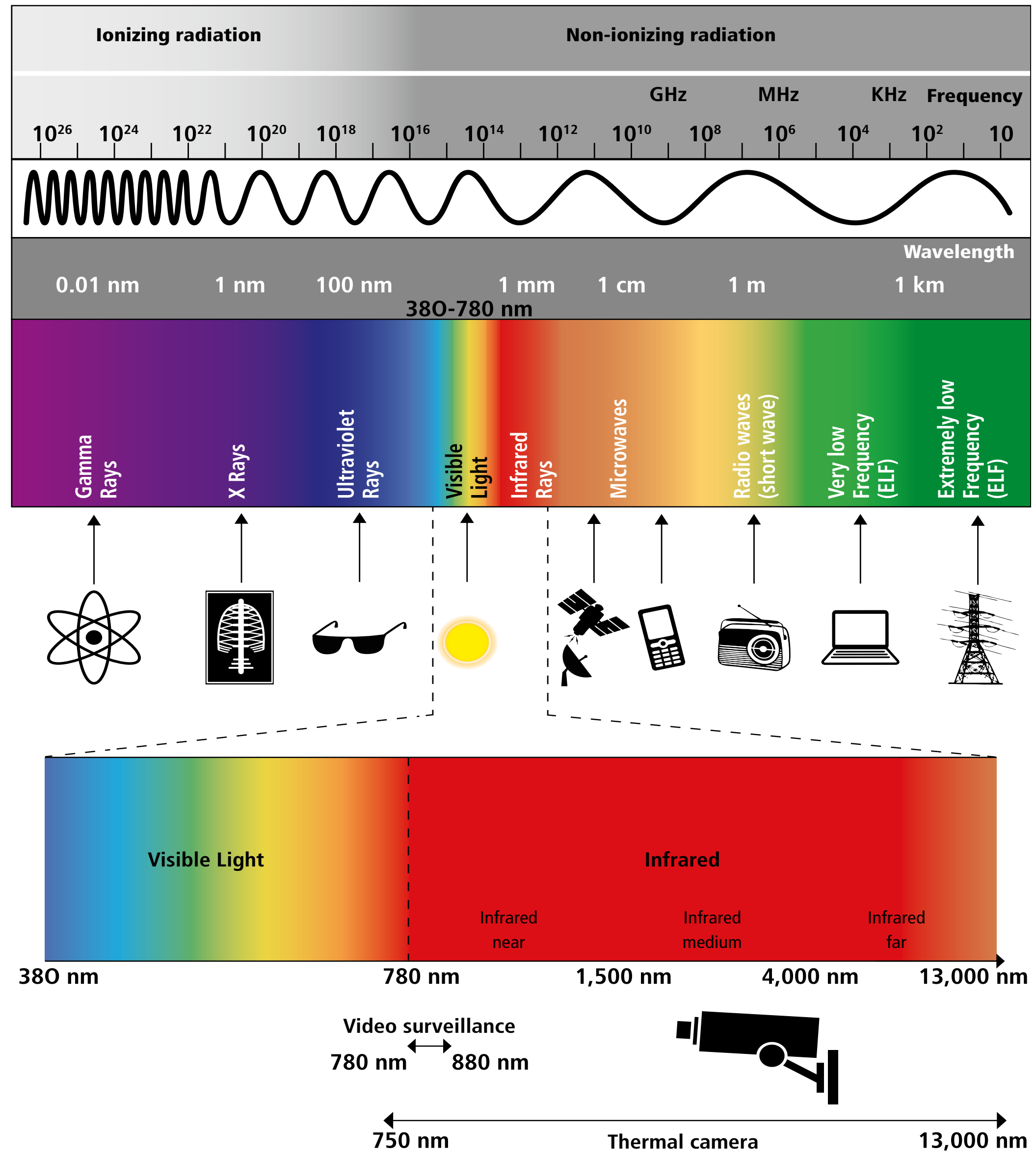


Figure 10 : The spectrum of light on the scale of electromagnetic waves

To observe bats , our " visible light" would be sufficient if bats were not especially sensitive to this spectrum and if we had eyes extremely sensitive to lower photon* such as owls or the lynx, which have excellent night vision. Indeed, it is not possible to conduct a study of bats using conventional projectors and therefore, the infrared spectrum is of interest to us.

Infrared is, in the continuity, the visible light but, like most animals, human beings are not sensitive to it. To see infrared, we must use a digital camera with an image sensor which is "naturally" infrared sensitive.
However, we must distinguish between two types of infrared cameras that deliver quite different results :

- Conventional cameras for which the sensor is sensitive to near infrared (780 to 900 nm). They require the use of infrared illuminators to get a picture in the dark.
- Thermal imaging cameras that are sensitive to 13,000 nm and capture the infrared radiation of a body, that is to say their heat. They show the thermal image of a scene (*see* photo 1).

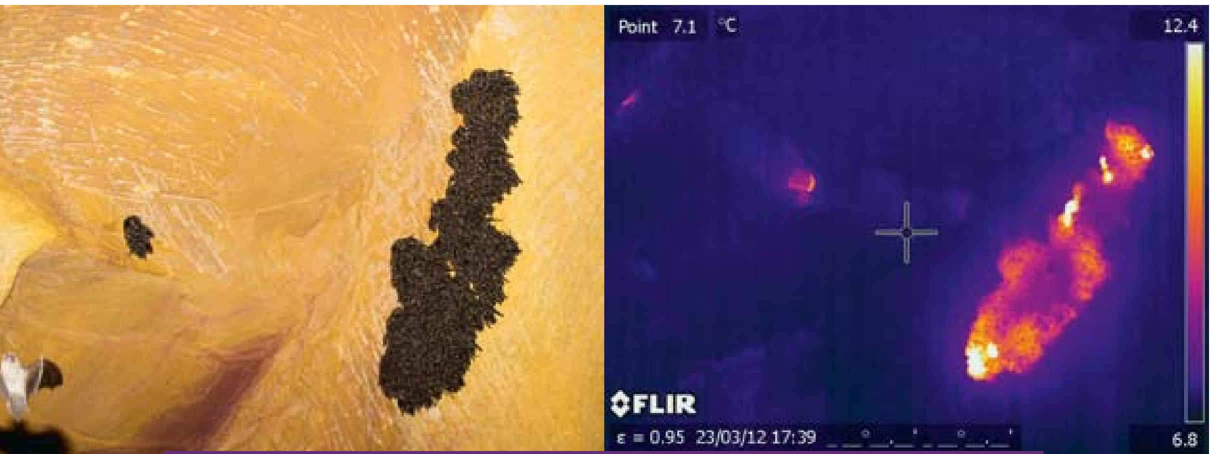


Photo 1 : Swarm of Miniopterus in a transit roost. *Left, photo taken with flash for counting ; and right, image by a thermal camera of the same swarm. More the animals are white, more they are hot.*

Thermal vision provides very interesting information about the animals in lethargy and the thermal distribution of individuals, as in photo 2.

The visible light may be sufficient for some twilight observations or when there is a full moon. The use then of light amplifiers, and ultra-sensitive cameras may be sufficient to observe or take shots. The results are very surprising from the moment there are still enough photons.

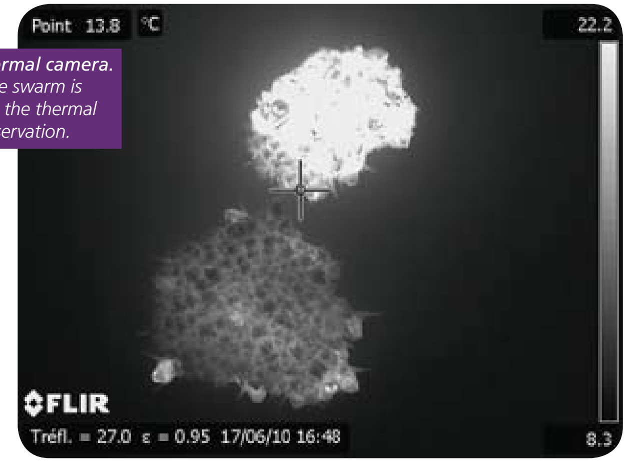


Photo 2 : Two swarms of bats by thermal camera. *It is thus possible to distinguish that one swarm is lethargic when the other is active. Only the thermal camera allows this kind of amazing observation.*

What sensor definition

Today the choice is great and it is possible to shoot in an equivalent definition to cinema quality at a "low cost". However, the higher the resolution, the larger the size of file to store, and the higher the price of equipment. The choice of definition depends on the purpose required. According to the objective, it is not necessarily vital to have a high definition. It is therefore important to identify need.

Difference between definition and resolution
The definition is the total number of pixels the sensor has. Resolution is the number of pixels per unit of measure, for example 300 pixels per inch (ppi) for printing paper and 72 pixels per inch for computer screen resolution.

High definition is not necessarily a guarantee of quality ,it depends on the processor that is behind the sensor. Furthermore, the larger the pixels, the more they are sensitive to light and the greater the possibility of having good performance in low light. The Nikon D4 has "only" a 16 million pixel full format sensor, sufficient definition for 98 % of users. This high-end Nikon is far from being the most defined, but it is the most sensitive device on the market, thanks to the electronics that manage the sensor.

Examples choice of material
• As part of the action A2 of LIFE+ Chiro Med, the objective of which was to study the distribution of animals compared to the temperature under the roof (*see* photo 3), during the day but also during the season, shooting equipment adapted to the constraints of the specifications had to :
- take a picture every 30 min. for several weeks without the intervention of a technician,
- photograph in infrared so as not to disturb the colony,
- photograph an area of 20 m² with very little room,
- have the ability to zoom in to count individuals,
- have the ability to retrieve the recorded images while remaining thirty meters from the colony.

The solution was to turn a camera with a 24 mm lens to a definition of 12 million pixels.

Photo 3 : Infrared photograph of a mixed colony of Greater Horseshoe Bats and Geoffroy's Bats taken as part of action A2.

• As part of the filming of a documentary, definition of 2K (1,920 x 1,080) or full HD* is required. For the film "Life of the Greater Horseshoe Bat", the full HD was chosen because today it is the standard for broadcasting. However, cameras 4K (cinema standard) were used for the slow-motion pictures (*see* photo 4).

Photo 4 : Phantom Camera 4 million pixels which can record 1,450 frames per second.

• In the context of video surveillance of a colony of bats, with the objective of sensitization and with the constraint of putting the video live on the Internet ; the choice should be of a video surveillance camera, the definition of which does not exceed 720 x 576 (414,720 pixels, DVD standard). This definition is sufficient for this purpose, it does not overload the network and allows better video fluidity. For the Internet, it is necessary to find a good balance between adequate definition and a flow of images as close as possible to 25 fps.

It should be recalled that the flow of images are compressed by the camera or video camera when they leave the sensor. The famous codecs ("co" compressor "dec" decompressor) allows to save on kilobytes* but degrades the image. If the equipment allows, it is necessary to also find the right balance between an efficient compression and sufficient image quality for the objective sought.

Management of the mass of information recorded

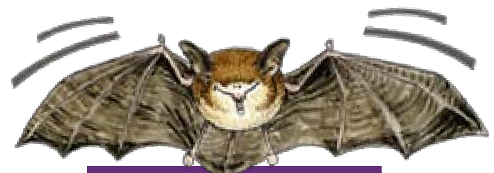
The mass of data collected during a film or a study with imaging techniques is very important and the storage and classification of images should be planned before the start of the acquisition.

Examples

• For the film "Life of the Greater Horseshoe Bat", there are approximately 5,000 gigabytes (5 terabytes : 5 TB) of high-resolution images that are currently stored, about 10,000 video clips. All the images are stored although 10TB are used. All images are archived, via imaging software which allows for their classification withsets of keywords such as location of shooting, the species concerned, the filmed behaviour, the equipment used, the technique used, etc. Archiving is an important step that must be carefully performed because if a keyword is forgotten for an image, it will not appear in your later research.

• To carry out the study of the behaviour of a colony of Greater Horseshoe Bats in their breeding roost in terms of the temperature which changes throughout the day (dawn to dusk) and the period (May to October), compact automated cameras were used. More than 22,000 images were recorded over about 5 months of study which required storage for about 70 gigabytes (70 GB). In this case, archiving via keyword can be reduced to the specific location information of the shot, the number of the camera and the timestamp*. A very important point to remember is to ensure that the shutter movement and the timestamp on the devices are synchronized (shooting apparatus, as well as other accessories such as a weather station for example).

Several pieces of image classification software are now on the market, "Adobe Lightroom"is certainly the most advanced software for the general public.



TIPS

- Managing the mass of information is a long but essential task for using and developing an image bank.
- This step should not be overlooked.
- Enough time should be put aside, that is to say, for specific archiving, at least as long as the duration of the shooting or the actual time of filming.

DIFFERENT TECHNIQUES

Warning : *Digital equipment is constantly and rapidly changing, this technical guide presents only the types of equipment likely to respond to the needs of a study of bats. Examples of models of equipment are given in the knowledge that they will be quickly overtaken, in 3 to 5 years by a new generation.*

The importance of the locations and the complementarity of techniques

To observe and/or record the behaviour of bats, careful preparation is a guarantee of success. The first preparatory step is identification. This step can be long, but must not be neglected.

Examples

• In the case of the study of road crossing by the Greater Horseshoe Bat by LIFE+ Chiro Med (Action A6,*see* Guide technical No.1 "Systems to help with the crossing of roads") :

- The study carried out on hunting grounds, which was achieved by using telemetry, served to rough out the research work by highlighting the flight routes used by animals (Action A5).

- At the same time, a mapping analysis was performed to identify road black spots, that is to say the places or the corridors (linear vegetation) which were cut over by a road.

- Then, sound recordings were made with automatic ultrasonic detectors (Anabat™) during whole nights at the "black spots" identified. This was to refine, down to a few metres, the road crossing places used by animals, and to know during what time they used it through timestamp records.

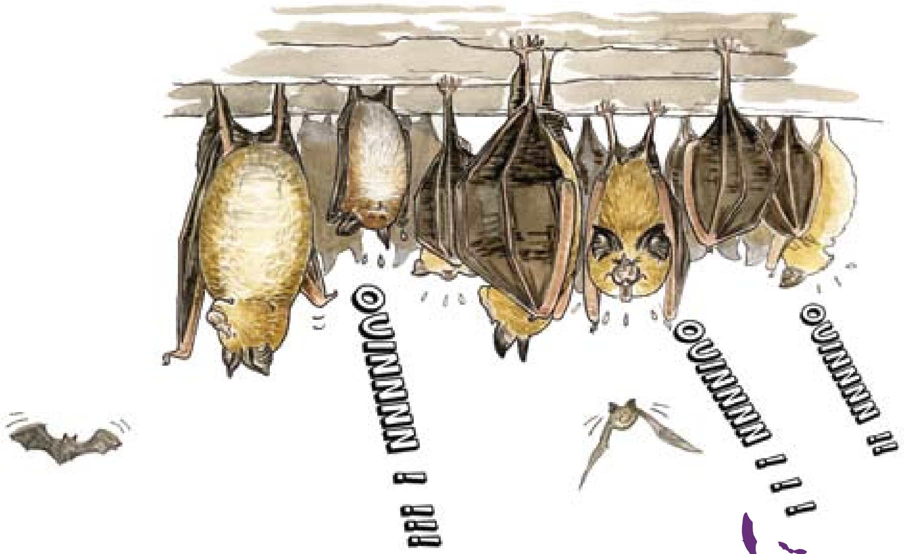
This fine research then allowed for the placing of imaging equipment at predetermined points of passage over several nights ; and to complete, with the maximum rate of success, video recordings to understand how Greater Horseshoe Bats cross roads and what behaviours they adopt when a car arrives.

We see from this example that video recording does not replace any other technique, but all techniques are complementary. The video is an additional tool fused to gain a better knowledge of the species, including its ethology. This data on their flight behaviour is a useful source of scientific information, helpful for the management of and protection of the species.

In addition, all information gathered was used in certain sequences of the film "Life of the Greater Horseshoe Bat", a communication tool for raising awareness about bats to a wider audience (Action D4).

Photo 5 : *Infrared photography of a colony of Greater Horseshoe bats.*

• In the case of video surveillance of a colony within a large attic or church roof (*see* photo 5), a minimum of research is also required. It is necessary to carry out one, or several visual observations the year before any installation to determine the best places that the bats occupy. Unless your budget allows you to install cameras and projectors to cover the entire surface



Precautions before installation in a roost

To avoid unpleasant surprises such as the desertion of a colony, mortality of individuals or damage to the equipment, certain precautions should be taken when installing equipment within a roost :

Period of installation of the equipment

In relation to studies that require the installation of equipment inside a breeding roost, it is imperative that the fitting takes place during the absence of bats. In preference this is done in winter when bats are in their hibernation roosts (absent for the season) because it is then possible to work during the day in the roost. If this is not possible, you need to install the equipment at night, when bats have left to go hunting.

But beware, when females are in late gestation and/or the birthing period, any penetration inside the roost is unacceptable, even at night. A number of females remain permanently in the roost with new born and/or young that are still not flying. To shoot sequences in the summer, the material must be placed in the roost before the critical phase of late gestation and parturition (risk of abortion and mortality of newborn caused by stress).

Noise nuisance of equipment installed

Installed equipment (camera, power supply, etc.) should be tested beforehand with an ultrasound detector to verify the absence of ultrasound emissions. You need to place the detector 20 or 30 cm from the device under test and try over several frequencies.

A certain number of devices do emit ultrasound but solutions are possible to overcome this problem. These solutions are :

- Avoid transformers (powers various electrical equipment), which generally generate ultrasounds, being within a radius of 3 to 5 m of bats, or if this is not possible put this equipment in a box (fireproof box or non-flammable material) to stop the ultrasounds.
- Avoid installing equipment that has a cooling fan, favour passive cooling systems.
- Beware of electrical cables that can also generate ultrasound when the power flow is active.

Cabling

Whatever cables are installed in the ceiling, they should not hang down because this can potentially be a mortal danger to bats. They may in fact get stuck in the cables, causing injury or hanging (*see* photo 6).

If the presence of rats is confirmed, it will be necessary to put the cables in a metal conduit to protect them from the teeth of rodents.

Photo 6 : Greater Horseshoe Bat hanging in old iron wire. He was saved at the last minute.

Electricity

For all systems that require electrical power directly from the network, check their quality. Power cuts or surges can cause failures in the devices used. Knowing the quality of the network also allows for better analysis of the origin of an equipment malfunction in the case where this occurs.

To minimize the inconvenience caused by a discontinuous electric current, it is possible regulate the current with an inverter* or to use a car battery (in the case of a 12 volt system) maintained by a charger.

In the case of an installation in a place without electricity, car batteries prove a useful alternative. They allow autonomy for several weeks. You should have secondary batteries to rotate between those which are discharged and those which are charged, thereby having no interruption in the study on course. If possible, the ideal is to couple the batteries to a solar panel. Warning, you must ensure that the panel is powerful enough to charge the battery faster than the discharge.

Protection of equipment

The installation of a monitoring system for bats in a roost can suffer from both guano and droplets of urine. It is therefore imperative to install the equipment away from the area where bats hang; that is to say not directly under their preferential sites which need to be identified in advance. Also, be sure to protect all equipment with a plastic film (apart from the lens and ventilation duct) to guard against corrosion and to avoid large scale cleaning at the end of the study (*see* photo 7).

As for the lens of the camera, this must be protected at least with a neutral filter (no colour cast) and a hood.

Photo 7 : Camera used for the film "Life of the Greater Horseshoe Bat."
Note the matt box which protects the lens from extraneous light, but also from projections of guano.

The different types of night vision tools

The light amplifier

The light amplifier resembles a pair of binoculars or a monocular (*see* photo 8). It consists of a lens on one side and an ocular on the other. A light amplification tube is installed between the two. This tube is a vacuum chamber where a photocathode* is situated. Photocathode's convert photons into electrons.

When a photon enters the vacuum chamber, it strikes a first photocathode which releases an electron discharge and can recreate a brighter image on the phosphorescent screen which is the other end of the tube. It is the phosphorescent screen which produces the typical green-yellow picture.

Inside the tube, multiple photocathode's may be used which amplifies the signal. The brightness gain varies between times 1,000 and 50,000 depending on the generation of tube amplifier !

Photo 8 : Light amplifier (left) and image seen through such an amplifier (right).

Differences between the generations of tube

This type of material is very light and handy. There are different generations of light amplifier (*see* Table 1). They fit easily into a bag or pocket. They are therefore ideal for observations in difficult environments, table 2 summarizes the advantages and disadvantages of such a device.

The light amplifier is however a fragile tool. The tube can indeed age rapidly if is exposed to repeated glare. Be careful when buying second hand equipment.

Table 1 : Comparison of different generations of light amplifier.

Generation	Amplification factor	Photocathode sensitivity (in mA/lm)	Resolution (line pair / millimeter, = lp/mm)	Life (in hours)	Average price (in €)
0	operating equipment only active in infrared = Requires an IR projector.		55		Second hand equipment
1	Until 900x	120 to 250	25 to 35	2,000	100 to 300
2	10,000 to 30,000x	240	32 to 50	3,000 to 4,500	1,100 to 3,000
2+	20,000 to 35,000x	600	35 to 60	3,000 to 4,500	2,000 to 4,500
3	30,000 to 50,000x	Between 900 and 1,600	45 to more than 72	10,000	Until 10,000

Binocular or monocular ?

Certainly, it is more comfortable to observe with both eyes . However nocturnal viewing through a light amplifier has the effect of getting the eyes used to the brightness and it takes between 15 and 45 minutes for the eyes to get used to the dark again, which can be dangerous in the field. The advantage of the monocular is that it allows you to keep an eye with a very open pupil, and to keep a good natural night vision.

Concerning the observation of bats, the light amplifier is ideal for counting the individuals leaving the roost. Associated with a small infrared spotlight, often built into the device, it allows you to observe animals in total darkness without disturbing them with visible light.

The disadvantages of the monocular

- The amplifiers come with an optical field the angle of which is very small. Thus, for performing a count at the entry of a large cavity, the low optical field makes the counting difficult.

- Amplifiers give a milky picture when twilight is still present, bats are hardly visible.

- The amplifiers are sensitive to glare. During observations of Greater Horseshoe Bats crossing roads the amplifier could not be used due to glare induced by vehicle headlights and the twilight.

The amplifiers of generation 1, associated with a small infrared (IR) projector, are inexpensive and are very useful for observing bats within 5 to 8 m. However, these are modest tools that do not have the qualities of a superior generations and the image is often sharp at the centre but blurred at the edges

The range of amplifier models is very large. There is a wide variety of qualities so it is necessary to try out the equipment before purchase.

Table 2 : Advantages and disadvantages of a light amplifier.

Uses : - *Counting on leaving the roost.* - *Observation of the colony.*	
Advantages	**Disadvantages**
- Night observation. - Sensitive to near infrared. - Lightweight and manoeuvrable. - Autonomy very good (dozens of hours).	- No integrated video recording. - Cost not negligible. - Angle of vision rather small (some models allow the change of lenses). - Premature aging of the amplification system if repeatedly subjected to glare.
Cost example : between 100 to 10,000 €.	

There has been in existence for a while digital light amplifiers where the amplified image is no longer recreated on a phosphorescent screen but on a digital sensor. They offer the advantage of being equipped with a video output that can be connected to an external video recorder (style MPR Yukon).

Ultra sensitive camera

Photo/video equipment is constantly changing but it is only since 2009, with the production of the Nikon D3s (which was the first to pass the milestone of 100,000* ISO sensitivity) and especially since 2012 when the company released the Nikon D4[1] with 204,000 ISO and a real video function things got really interesting in terms of bat observation simply by twilight or the light of a full moon. Table 3 summarizes the advantages and disadvantages of such a device.

In parallel, the company Nikon has released new optics which are very bright and very high quality. These lenses are 24, 50 or the 85 mm which open at f/1,4. The 200mm telephoto also has a large opening lens (f/2.0). The Nikon D4 (*see* photo 9) associated with optical light today allows us to shoot scenes when it is almost night time, or in any case, beyond what can be seen by the human eye. Videos made at very high sensitivities provide a rather poor picture but at 25,000 ISO, the quality for scientific or naturalistic observation is fine.

Photo 9 : *DSLR Camera Nikon D4 with a 24mm lens mounted on a tripod.*

[1]***Nikon D4 :*** *at the time this guide is being printed, Nikon has announced the release of the Nikon D4s that displays a sensitivity of more than 400,000 ISO !*

This type of equipment is evolving, it already gives interesting results but it is expected that by 2020 or 2025 it will be possible to get very good results with just the moonlight

Canon is no exception and its EOS 1D Mark IV camera is on the heels of the Nikon D4. Canon also announced in early 2013 that it was developing a new sensor "CMOS" ultra-sensitive that will shoot using just the moonlight.

In the case of use in the spectrum of visible light and therefore with a colour rendering,

this type of material is beginning to be effective for the observation of bats, but still flirts with the limits of equipment technology. These ultra- sensitive cameras can only be used within the 30 or 45 minutes of dusk or dawn, with a bright full moon or with direct or reflected light pollution * of clouds . However, to observe bats in dark places, it is quite possible to use a red lamp such as a head torch, but in this case , the observation is limited to within the light beam

Table 3 : Advantages and disadvantages of ultra- sensitive cameras.

Uses : *Study of behaviours in twilight flight.*	
Advantages	**Disadvantages**
- Twilight observation in colour. - No need for a light source. - Night observation possible by adding a small red lamp. - Video recording HD 1 080p. - Possibility of slow motion 2x. - Wide range of lenses, from wide angle to telephoto.	- Inability to shoot on a dark night except with the addition of a small red lamp (head torch style). - Cost not negligible.
Cost example : about 6000 € Body only + 2,000 € for a lens 24 mm or 85 mm f/1.4 + 500 € for a 50 mm f/1.4 + 6,000 € for a 200 f/2, a total of 16,500 € TTC for a complete outfit.	

Thermal camera

Thermal imaging cameras are not sensitive to visible light. Their sensors use the infrared spectrum of rays that begins at the limit of visual perception in the deep red, or near-infrared at 750 nm and have a visibility up to 13,000 nm ; below the limit of this this spectral band is extreme infrared at 100,000 nm.

Thermal imaging cameras are nowadays unparalleled tools which possess two important advantages for the study of bats. They are bot :

- A high performance tool for night vision.

- And an equally efficient tool for measuring surface temperatures.

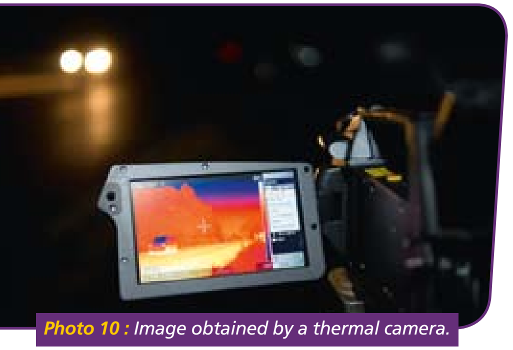


Photo 10 : Image obtained by a thermal camera.

They are pieces of high-tech equipment that can perceive the smallest change in the temperature of the subject observed, with remarkable precision for the "very high range" cameras (*see* Table 4).

You should know that the vision obtained gives the same rendering day and night.

You can observe (*see* photo 10) that car headlights do not dazzle the camera sensor. The sensor being responsive to heat energy from the environment but not to visible light.

A night vision tool

To see at night, thermal imaging cameras have almost no limits. They are autonomous in terms of lighting as it is not necessary to add any other infrared illuminators or light source, which would have no effect. They'll allow you to see without limit of range. Thus, a bat will be visible as long as it fills at least one pixel of the sensor.

But this visibility depends on the distance of the animal and the lens used. In practice, the perception of temperature contrasts is not always optimal because an important factor needs be taken into account : thermal differences. A thermal imaging camera sees body heat and distinguishes to us an image if, around the body, the temperature is sufficiently different. The observations made in the summer, in the Camargue, were difficult because of the differences in temperature between the vegetation and the bat were sometimes below 4°C. Thus, a temperature difference range of 15 to 20° C is ideal for watching a bat in flight in its environment.

It is within this constraint, that the "high end" cameras make a difference because they have a very high sensitivity. They can distinguish a bat in flight against vegetation with a very low temperature difference which would have been invisible with a camera of lower quality.

The drawback with thermal cameras is that it is almost impossible to observe bats in hibernation. Since bats reduce and regulate their body temperature to the temperature of the cavity, between 0 and 10°C. The cavity (cave, tunnel...) and animals are thermally homogeneous. To distinguish the shape of the cave or the cluster of bats in lethargy is impossible without being close to the swarm. Indeed, the image being composed by temperature differences sensed by each pixel, if the temperature of the body and the material are homogeneous, the image will also be. On the other hand, in a cavity which is ventilated, it will be possible to see the effects of air currents and perhaps to understand where the bats have chosen to place themselves during hibernation, or in transit, within the roost.

Tools to measures surface temperatures

Calibrated thermal cameras are thousands of highly accurate thermometers. In effect, each pixel is independent and is a point of measurement.

A camera that has a resolution of 640 x 480 pixels, has 307,200 thermometers !

Tableau 4 : Comparison between different models of thermal imaging cameras.

	FLIR Scout PS32	Modèle FLIR E60	Modèle FLIR SC660
Native sensor resolution in pixels	320 x 240	320 x 240	640 x 480
Frequency (fps)	9	60	30 to 120
Pre-registration	No		Yes 7 seconds via software
Sensitivity at 30°C	?	0.05°C	0.03°C
Autonomy	5 hours	4 hours	2.5 hours
Interchangeable lens	No	No	Yes
Price in € (approximately)	3 000	7 000	45 000

Thus, it is possible to simultaneously measure the temperature of several individuals, measure the temperature of the roost, to identify cool areas or identify existing air currents (*see* photo 11).

In conclusion, anyone who wants to use a thermal imaging camera, and to have reliable data, must be trained in this technology. Table 5 summarizes the advantages and disadvantages of such a device.

Photo 11 : Example of an image obtained by a thermal camera (FLIR SC660), the bats are represented in yellow and the different shades of purple show temperature differences.

TIPS

Measurement of the temperature of a body or more subtly, several bodies, requires a basic knowledge of thermography or you run the risk of getting results that are totally wrong.

You should know that at the same temperature, a beam, a wall or even the wing of a bat will give different results. Wood, stone and skin do not have the same emissivity*. It is therefore imperative to enter in the camera settings the emissivity of the subject you want to analyze. Moreover, the environment, the air temperature, humidity, subject distance, etc., are all parameters which will influence, by more or less, the results and it is therefore necessary to take them into account.

Table 5 : Advantages and disadvantages of the thermal camera.

Uses : - *Study of behaviours during twilight and night flight.* *- Study of the behaviour of thermal regulation in bats.* *- Study of the temperatures in bat roosts (cavities and buildings).*	
Advantages	**Disadvantages**
- Unparalleled night time observation. - Insensitive to glare (eg. car headlights). - Measurement of temperatures. - No need for light source. - Raw video recording. - Pre-registration via computer. - Portable and handy.	- Difficulty in observation when there was a small thermal difference. - Requires training for thermal analysis. - Requires a computer to make raw recordings over 10 secondss. - Weight of raw video recordings very large (about 1 GB per minute). - Cost high for a quality model needed to study bats

Recordings

It is possible with some thermal cameras to produce raw recordings. That is to say, to record everything that the sensor distinguishes as information before treatment by the software that provides a final image. This record is very interesting because it permit's subsequent reworking, very importantly, of the image to obtain for example the right setting which will allow you to distinguish bats against a background of vegetation, which is virtually equivalent to the body temperature of the animal.

Raw recordings consume about 1 GB per minute. Setting the pre-registration function is important because it can trigger the instant the bat passes in front of the lens so saving a few seconds before it fires. This function allows you to not miss the beginning of the scene or the entire plan ; and also allows you to save space on the hard disk data backups.

Depending on the camera model, it is possible to perform a recording directly with the camera, but only for a few seconds. For longer recordings, you need to add a computer system and software for controlling the camera.

Monitoring equipment

Between equipment that is ultra-sensitive to visible light and a thermal camera that captures body heat, there exists equipment that is sensitive to "near infrared" (750-900 nm).
The "near infrared" is located in the deep red and is no longer visible to animals or Man.

All camera and digital camera sensors are sensitive to near infrared. The problem is that these electromagnetic waves affect the quality of the image taken in visible light. Therefore, most of these digital devices are protected from these waves by an anti infrared filter placed in front of the sensor. This loss of sensitivity makes them therefore unsuitable for the study of bats.

However, there are a large number of video cameras which are devoid of the filter or on which it can be retracted.

Cameras sensitive to "near infrared" are not thermal cameras and are not light amplifiers of more than a few photons.

The "near infrared" cameras need light to see at night and must be coupled either with a conventional projector (of little interest in the study on bats) or a infrared projector. Infrared projectors are projectors that produce a "luminous" beam which is invisible because it is in the range of "near infrared", and they can be used as conventional projectors.

Whatever the equipment used (video or photo), for monitoring this nocturnal wildlife, sometimes major logistics are required. Especially when it is necessary to shoot from a distance (control point away from the camera) and/or to take shots over long periods.

Infrared projectors

There are a multitude of infrared projectors on the market at all prices. These projectors are often overlooked when purchasing equipment, although it is an essential element for a complete outfit.

Manufacturers and vendors display extreme performance detail for these projectors and give the impression that, with an IR projector, it will be possible to light up to several dozen metres.

For example, a projector of a model with 318 leds of 10 mm is theoretically supposed to illuminate up to 85 feet or 300 m. In practice, divide this by 10 or 20 in the context of observing bats.

Projectors of 140 leds of 3 mm (a very widespread projector, *see* photo 12) is a minimum needed to start a package of video surveillance equipment. This type of projector can illuminate a surface of about 1.5 to 2 m^2 and up to 2 m distance with sufficient power for good image quality.
To improve the homogeneity of the illumination, it is possible to put a diffuser in front of the projector but in this case, the power is reduced.

Photo 12 : *Infrared projector of 140 leds of 3 mm (a widespread product).*

To avoid all new sources of noise and/or ultrasound emission in the roost, projectors must not have an integrated ventilation system but a passive cooling fan. If the projector has a ventilation system, disconnect it and remove the glass in front of the leds so cooling can occur.

Camera video surveillance

Video surveillance is growing and today there is a lot of different equipment available. Originally used for security checks or for public safety, it can be diverted to scientific study and/or for raising awareness of bats.

Video surveillance equipment is made to be used remotely. This varies from a few metres, when the control point is in an adjoining room from where the colony is observed. But thanks to the Internet, viewing from a distance (image transmission) extends today to infinity. Monitoring a colony of bats can be done anywhere in the world provided there is a connection to the Internet.

Equipment on offer is now very varied and very powerful. Surveillance cameras PTZ (pan/tilt/zoom) are perfect for the study of bats inside their roosts. These are controllable remotely and adjustable in all directions (*see* photo 13). They provide 25 fps and are often equipped with a powerful zoom of approximately 18x, 29x or 45x for the optical zoom.

Video surveillance is practical and is recommended for observing bats during their daily lives (in breeding roosts). These behavioural observations may have a simple goal of ethological study but may also be related to a physical parameter such as the temperature and/or humidity of the roost.

If the colony of bats is installed in a building in a village, video surveillance can serve as an advocacy tool. Images can be transmitted directly to a room that is open to the public. For more attractiveness and interactivity, the public can control the camera via a joystick*. In addition, some video surveillance cameras have a built-in server. That is to say they can be connected directly to the Internet and are remotely accessible at all times and by different people via the Internet.

DIFFERENT TECHNIQUES

Photo 13 : *Video surveillance cameras IP (Internet Protocol) - PTZ (pan/tilt/zoom) with its infrared projector 140 LEDs, and a photograph taken from the video monitoring (center). The camera is protected by a plexi-glass bubble.*

In practice, the video surveillance of a colony requires heavy logistics : cameras are connected to a computer through a large network of cables which need to be set up and controlled. They require a reliable source of electricity. However, these CCTV systems provide very good or excellent results if the chosen material is well suited to the problem.

Several manufacturers produce video surveillance cameras like Sony, Axis or Panasonic. Their model range is very wide and designed to suit all budgets.

For bats, ensure that the properties of the camera are at least the following :

- PTZ camera (pan/tilt/zoom).
- 25 fps at full resolution.
- Zoom 18x minimum.
- Minimum 720 x 576 pixels or Full HD 1080p.
- Day / Night function to benefit from a sensitivity of near infrared.
- Memory card slot for recording without any external equipment.

There are also video surveillance cameras which are thermal cameras. Axis and FLIR offer several models.

Analog video surveillance camera on a turret that allows for panoramic horizontal and vertical views.

T. Stoecklé

Example of video surveillance of a colony during a season (May to September)

Certainly, the first difficulty to overcome is access to the electricity grid. Video monitoring of a colony of bats during a season is only possible for a species that roost in buildings, or in close proximity, and where access to electricity is possible. Without the electrical network video surveillance of a colony is possible only if you can equip the site with solar panels.

For example in 2009, the Bats Group of Provence was able to conduct a study of a breeding colony of Large and Small Barbastelles at the Ecrins National Park thanks to the fact that the colony was located in the heart of a village. Access to electricity was assured. It allowed the use of this type of equipment and to achieve the objectives of the study : to relate behaviour of bats with the temperature of the room, and to raise public awareness through recorded video (see photo 14).

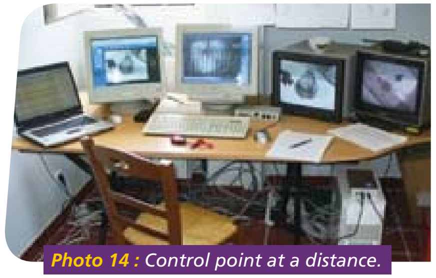


Photo 14 : Control point at a distance.

Photo 15 : Equipment installed in the attic of a building in the Ecrins National Park.

Photo 15 presents only the equipment installed in attic (there was also control point equipment)

- 1 digital camera ptz[1] equipped with a zoom of at least 25x with day / night function; definition 640 x 480 pixels ; 25 frames per second at full resolution ; integrated server ; controllable remotely via the Internet.
- 3 analog cameras with excellent definition and a very high sensitivity ; resolution 720 x 576 pixels ; definition 540 TV lines.
- 3 zooms (one wide-angle 2.6x and 2 telephoto : 6x and 15x).
- 2 motorized pan / tilt heads that guide cameras non ptz left to right, and from bottom to top.
- 2 ptz controllers : can control from a distance the motorized heads and the zooms of the analog cameras.
- 2x 17'' monitors.
- 15 infrared projectors 140 LEDS + transformer.
- 450 meters of various wiring.
- 1 PC with frame grabbers and the video surveillance software "Digivue" which gives the ability to record videos from 4 cameras at 25 fps. This computer can be either the control computer or server for a remote control.
- A weather station Hobo with 4 thermos sensors(*see* photo 16).
- A power source.

It should be noted that this material is already old but it is still very good. The cost such a set up is about 15,000 € (delivery included).

[1] ***ptz*** : ***p****an/****t****ilt/****z****oom ; means that the camera is mobile in all directions and has a zoom.*

Photo 16 : Example of a HOBO weather station (inset) installed in a roost of Greater Horseshoe Bats and Geoffroy's Bats. *Thermal probes are placed at distances from each other, by a long cable, to measure the temperature at specific points in the roost.*

Photo monitoring

Photo monitoring will be chosen when is not necessary to observe the bats continuously. Unlike video, photo monitoring allows for very high definitions and therefore images for counting individuals in a large colony. Autonomy in terms of memory and energy is another of its strong points because it allows monitoring over very long periods without the intervention of a person.

For the study of bats it is necessary for the equipment to be sensitive to "near infrared" and one or more infrared projectors is needed to illuminate the scene.

Unlike video surveillance equipment, the choice of photo monitoring equipment is much less important. There are devices on the market designed for the observation of wildlife. They are waterproof, can fire in a programmed manner (a photo or short video can be taken) or work by motion detection. This material has a fairly high degree of autonomy because of the power level needed for shooting (up to 30,000 photos).

However, this material is not adapted for the study of bats but it can be used to monitor bats in small roosts. The integrated infrared illumination system is not powerful but some models can fire additional projectors.

This equipment is suitable if the goal is to have information about the presence / absence of bats in small roosts (less than 5 m²).

At the time of writing this guide, there is no photo monitoring equipment on the market which is very good for observing bats. This is explained by the fact that :

- The trigger sensor of this equipment is fired by heat and movement. It takes a combination of these two elements for there to be a shot. Bats are (overall) very light and emit only a low heat (at least for the sensors on these devices) which deteriorates or cancels out detection.
- Reaction time (time between detection and shooting) of the cameras is at best 0.1 s. Which is fast for many species but slow for bats in flight.
- The shutter speed of the lenses of these devices is too slow to get exploitable shots of individuals in flight.
- There are currently no cameras with a wide angle (at least 24 mm focal length).
- Bats are dark in colour, active at night or in the darkness of their roost, small and very mobile.

As part of the study by LIFE+ Chiro Med into the behaviour of the Greater Horseshoe Bat and Geoffroy's Bat in relation to thermal variations in their breeding roosts, equipment was developed specifically from a compact digital camera selected for its technical characteristics. This device was modified to obtain equipment sensitive to infrared, programmable over long periods and from which pictures could be downloaded from 30 meters away (Action A2).

Note that if definition is not a priority, video surveillance equipment can be an excellent choice. Indeed, there are now some cameras "version high definition" (2 million pixels) that have a slot for a memory card in order to save images following the programming at the time of installation.

Example of the equipment necessary for the photo monitoring of a breeding colony of Greater Horseshoe Bats (program LIFE+ Chiro Med).

In 2011, the installation of photo monitoring was carried out to study the behaviour of the colony in relation to the temperature of the roost. The peculiarity of the equipment was that each device was divided into two modules. The two modules were connected by a special cable. The "shooting" module consisted of a camera IR-sensitive and an infrared projector. The second module was composed of the remote control system for the device and removable memory (*see* photo 17). It was on this removable memory that the images were recorded.

Photo 17 : *Modified compact camera, protected and connected to a programming box for the automatic triggering system, and storage of data (frames), which is synchronised to other identical devices.*

DIFFERENT TECHNIQUES

This set up allowed the recovery of, at any time, the images taken by the camera that was located just below the colony. Thus, without disturbing the bats, we could see the photographs but also program the device differently (time between 2 photos, exposure, diaphragm, etc.).

Photo 18 : *The complete shooting system used for photo monitoring a breeding colony of Greater Horseshoe Bats.*

The complete system for the set up (*see* photo 18) thus comprised of :

- 1 compact camera in a waterproof box,
- 1 box containing the industrial programming automaton and memory for the images,
- 1 bobbin of 30 metres of special cable,
- 2 batteries of 12 volts and 50 amps per hour (12V, 50A/h) ; the second battery is intended to replace the first during charging,
- 1 Weather station "Hobo" with 4 sensors.

completely autonomous with a battery of 50 amp/hour, this system is capable of running for 10 to 15 days at a rate of one image every half hour.

Each camera was coupled with an IR projector of 140 leds of 3 mm in diameter. Despite this rather powerful projector, it was necessary to realise an exposure of 1 second for the photo to not be underexposed (too dark).

However, to illuminate homogeneously as possible the surface to be photographed, a sheet of tracing paper was installed in front of the projector, reducing its power by 3 or 4 times (*see* Photo 19).

The cost of a complete system was a little less than 3000 € (without the hobo station).

Photo 19 : *The system put in place for the photo monitoring of a breeding colony of Greater Horseshoe Bats.*

Fast video camera

Fast video cameras are cameras that allow you to take hundreds or even thousands of frames per second. The interesting point about this equipment, which is extremely clear and very expensive, is obtaining slow motion images which are very sharp, thus making it possible to observe behaviour totally imperceptible to the naked eye.

Bats are very nervous small animals (in summer roosts) and very fast (in flight). The use of fast video is required in the case of making a documentary film, for a ethological study, or a study of biomechanics.

Acquisition speeds needed to shoot bats are in the region of :
- 75 to 200 fps for a scene which is " wide" or "tight" in a roost.
- 150 to 300 fps for a close up scene of bats suspended, in the process of cleaning or scanning their environment ; and for a wide shot of an individual flight.
- 600 to 2,000 fps for a tight shot or a close up of a bat in flight.

Several models of fast video cameras are sensitive to "near infrared", thereby using infrared projectors to obtain the necessary light for shooting and not disturbing the bats.

The higher the acquisition speed, the more you need to add infrared projectors and/or use more powerful projectors. High power will also allow you to diaphragm and thus gain depth of field*.

The use of fast video cameras requires sizable logistics :
- A power source (generator).
- Many infrared projectors.
- Many cables.
- Tripods.
- A computer, etc.

The camera records video sequences which are uncompressed, which consume 1-32 GB per second shot, or more.

The world leader in the manufacture of fast cameras is "Vision Research" with its highly reputed "Phantom" cameras (*see* photo 20).
Its competitors include, among others : Photron , IDT , AOS system.

Photo 20 : *Phantom Model HD camera from the brand Vision Research, used for the documentary film "Life of a Greater Horseshoe Bat".*

V. Hénoux

Greater Horseshoe Bat.

CONCLUSION

Only 15 years ago, only light amplifiers could be used for observing bats. Digital video was limited in sensitivity, thermal imaging cameras were not democratised and therefore very expensive. Infrared LED projectors (non heating) did not exist. Slow motion was only possible with cameras whose limited sensitivity films required the use of very powerful projectors, extremely disturbing for bats. The photographer was working with films of ISO 100 to 800 and storage of computer data was on disks with 1MB of memory...

In just 15 years, and thanks to digital technology, the leap forward has been amazing. Tools for night vision have greatly benefited and their good performance will inevitably be improved in the near future.

Today, there are many versions of night vision tool. The equipment is very diverse and each tool has advantages and disadvantages. Each allows us to open the window on the night and observe the life of bats. Direct observation is a solution which today is realistic and possible, on the condition that suitable material is chosen to answer the questions asked, to achieve the objectives set and that the materiel is used in the right context.

Each study has its own technical requirements (*see* Table 6) and the material is more and more efficient to deal with. But we can also say that the higher and higher performance of equipment leads us to be more demanding in our studies and our research.
In all cases, the study of bats has benefited from technological quasi-exponential evolution of material, whether inside or outside the roosts (hunting areas, movement guided by ecological corridors, road crossings, etc.). The night vision equipment, combined with other techniques, such as telemetry or trajectography* allows an understanding of the ecology and biology of bats as never before.

However, bats are very difficult animals to study. And despite the evolution and the emergence of new efficient and appropriate technologies to observe and study them, only a detailed knowledge of these mammals will guarantee success in achieving the objectives sought.

Greater Mouse-eared Bat.

T. Stoecklé

Table 6 : Use versus type of equipment (- : not favourable to +++ : very good) :

	Light amplifier	Ultra sensitive camera	Video surveillance (near infrared)	Photo surveillance	Thermal camera	High speed camera
Naturalist observations, Night walking	+++	++	-	-	+++	-
Raising public awareness (direct observation)	++	+	+++	-	+++	++
Monitoring presence / absence over a long period	-	-	+++	+++	-	-
Counting on leaving the roost	+++	+ to +++ (depends on the site)	++ (in the roost)	-	+++	-
Thermal study in a roost / placement of bats	-	-	++ (synchronized with thermal sensors)	+++ (synchronized with thermal sensors)	+++	-
Study of behaviour in flight	+	+	-	-	+++	+++ (subject close)
Thermal regulation behaviours of bats	-	-	-	-	+++	-
Study of biomechanics	-	-	-	-	-	+++

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...

Depth of Field : distance between the first sharp plane and the last sharp plane in an image.

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).

Emissivity : the ability of a material to emit energy by radiation. A body subjected to radiation absorbs a certain amount but retransmits it. The emissivity is the magnitude that tells you how much of the flow is retransmitted after absorption.

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.

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.

Full HD : (Full High Definition) trade name which means a device (usually a TV or video monitor) which is capable of displaying at native resolution, an image consisting of 1,920 x 1,080 pixels, which makes an image of more than 2 million pixels. The definition of a DVD is 414,720 pixels.

Inch : unit of measure in length, 2.54 cm exactly (one-twelfth of a "foot" Anglo-Saxon measurement).

Inverter : a device for protecting electronic equipment against electric hazards. It is placed in a housing between the electricity network (connected to the sector) and the equipment to be protected.

ISO : measurement of the sensitivity to light of films and digital sensors. It is data essential to determining the correct exposure.

Joystick : computer peripherals with a handle placed on a pedestal. Buttons or knobs are also available on the handle or base. The user can move a device by moving the handle in one direction or pressing the buttons.

LED : Light Emitting Diode, an optoelectronic component that allows the transmission of monochromatic light.

Light pollution : artificial lighting of the night from dusk until dawn, which causes a real nuisance for nocturnal wildlife.

Lucifuge : Who shuns light. Said especially of certain animals that live in the dark.

Photocade : material capable of converting radiation into light by secondary electron emission, usually to allow its detection. It is a component of photomultipliers (light amplifier).

Photon : elementary particle (quantum) of light. The name photon comes from Greek and means "light."

Pixels : basic unit for measuring the definition of a digital image matrix. Its name comes from the English phrase "picture element".

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.

Timestamp : mechanism of combining a date and time to an event, information or computer data. It is generally intended to record the moment which an operation was performed. This usually results in the form of a sequence of characters representing the date and time at which an event occurred.

Tragus : projecting appendage inside the ear..

Trajectography : a technique allowing you to write the trajectory of a moving target from data obtained during its movement. The result can be 2D or 3D.

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.

D. Demontoux

Geoffroy's Bat.

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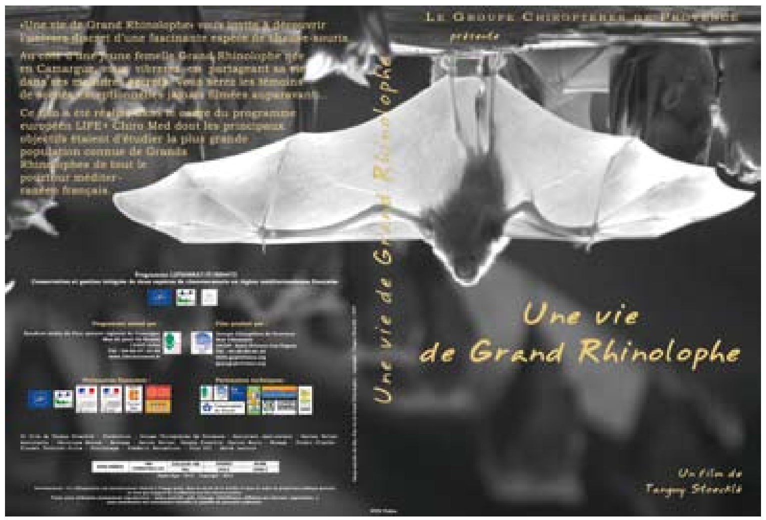
The reports of LIFE+ Chiro Med on different actions are available on the website :
www.lifechiromed.fr



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
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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

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