Acoustic Ecology of European Bats

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Species Identification, Study of their Habitats and Foraging Behaviour

Comments of the heterodyned sequences
Folder "2_Heterodyned sequences" of the Sound File

Sound File provided with the book *Acoustic Ecology of European Bats. Species Identification, Study of their Habitats and Foraging Behaviour*, Inventaires & biodiversité series. Biotope éditions, Mèze ; Muséum national d'Histoire naturelle, Paris, 2015, 368 pages.

In the following commentaries, click on the name of the desired sequence (for example "2.12") to listen to the corresponding audio recording (a warning will pop up, click on "allow"). The sequence opens with your web browser. Should you prefer to open the file with another software application, go directly to the .wav file on the Sound File without using the links below.

- **Sound File 2.1**: CF signals of *Rhinolophus hipposideros* (one individual at roost). Scan on either side of the zero beat (109 kHz), which is almost perfect at the end of the sequence.
- **Sound File 2.2**: QCF signals of *Eptesicus nilssonii* (individual hunting in an open habitat). The variations heard in the sonority derive from the Doppler effect, which gives an impression similar to when one turns the frequency variator of the detector. Detector on 28 kHz.
- **Sound File 2.3**: Flat-ended FM signals of intermediate duration of *Eptesicus serotinus* (one individual hunting above a meadow). Detector on 27 kHz. The variations in sonority are due to the Doppler effect; they are not as marked as in Sound File 2.2 because the QCF component is shorter.
- **Sound File 2.4**: Brief flat-ended FM signals of *Pipistrellus pipistrellus* (individual hunting along a forest border). The variations in sonority are due to the Doppler effect; they are not as marked as in Sound File 2.3 because the total duration is shorter still; sonorities heard are mostly 'tawp' sounds when on the zero beat and 'tick' sounds when below the FME. Detector on 45 kHz.
- **Sound File 2.5**: Steep FM signals of intermediate duration of *Myotis myotis* (one individual hunting over a meadow). Detector on 27 kHz. Since the duration of the signals is twice that of those in Sound File 2.6, the sonorities are richer. One should be careful not to confuse variations in repetition rate (see below) that induce a shortening of the signals – and therefore a slightly different audible structure – with variations in sonority (absent here). No sonority characteristic of a QCF component can be heard in this sequence (compare with Sound File 2.3, in which the hunting behaviour is the same).

- **Sound File 2.6**: Steep FM signals of short duration of *Myotis mystacinus* (one individual hunting along a forest border). Detector on 49 kHz. This sonority is typical of what can be heard in all the smaller species of genus *Myotis*. Remark: the flat-ended FM signals (quick rhythm and short QCF component due to the presence of numerous obstacles) of a common pipistrelle that twice passes by during the sequence can also be heard among the other signals. Can you spot them?
- **Sound File 2.7**: Short narrowband FM signals of *Barbastella barbastellus* (one individual hunting along a forest border). The sonority is 'duller' than with the small *Myotis*, but it does not vary with the Doppler effect produced by the bat's movement. Detector on 32 kHz.
- **Sound File 2.8**: Narrowband FM signals of short to intermediate duration of *Plecotus* sp. (one individual hunting along a forest border). Detector on 32 kHz.
- **Sound File 2.9**: *Eptesicus serotinus* hunting: 8 capture phases can be heard on this 50 s sequence.
- **Sound File 2.10**: *P. pipistrellus* at dusk in summer (high prey density), hunting near a hedge: fast and regular rhythm.
- **Sound File 2.11**: *P. pipistrellus* foraging by night in April (low prey density), more than 5 m from a hedge: slow and irregular rhythm.
- **Sound File 2.12**: *M. myotis* emits at a very regular rhythm when it is hunting above a recently cut meadow at dusk.
- **Sound File 2.13**: When insects are scarce, *M. myotis* alternates typical sequences with others characterized by their irregular rhythm, reminiscent of a common serotine (see Sound File 2.41).
- **Sound File 2.14**: *M. nattereri* exploring the foliage of overarching branches: the rhythm is characteristic, very fast.
- **Sound File 2.15**: *M. nattereri* can frequently leave the canopy to travel about underneath, along a track or in a clearing; the rhythm is then slower, like that of *M. myotis*.
- **Sound File 2.16**: *Myotis daubentonii* and *M. mystacinus* hunting together in understorey.
- **Sound File 2.17**: Social calls of *Pipistrellus pipistrellus* (20 kHz).
- **Sound File 2.18**: Sonar signals of a hunting *Nyctalus noctula* (20 kHz).
- **Sound File 2.19**: Stridulations of *Barbitistes serricauda* in heterodyne (25 kHz); note that at 33 s a bat passes by and adds its own emissions to those of the insect.
- **Sound File 2.20**: Stridulations of *Leptophyes punctatissima* in heterodyne (40 kHz). This species produces the highest-pitched emissions of European Ensifers; stridulations are very brief and rhythmic.
- **Sound File 2.21**: *Rhinolophus euryale* sequence (104 kHz), with at times *Miniopterus schreibersii* (represented by the second harmonic of its signal, whose first harmonic is around 53 kHz).
- **Sound File 2.22**: *Rhinolophus ferrumequinum* sequence (82 kHz); several individuals pass along a forest lane after having left the roost.
- **Sound File 2.23**: Edge of a cliff above a forest; a quick all-round scan with the electrostatic large-diaphragm microphone of the detector indicates by the varying intensity that the bat is flying along the cliff top over the drop; weak variations in sonority, in particular at first, but sometimes perceptible when the bat is flying away: **flat-ended FM signals**, zero beat at **34 kHz**; the bat is hunting (accelerations, revealing approach and capture phases); the combination of structure and FME designates *Hypsugo savii* as the only option; level of confidence: certain. Note the triple time rhythm (at 65 s, then again at 90 s and 95 s) sometimes heard in this species, but more commonly and typically in *Eptesicus nilssonii*.
- **Sound File 2.24**: Edge of a cliff above a forest; a quick all-round scan with the electrostatic large-diaphragm microphone of the detector indicates by the varying intensity that the bat is flying along the cliff top over the drop; rich sonority with much variation: **QCF signals**; zero beat at **33 kHz**; the bat is hunting (accelerations, revealing approach and capture phases) but the rhythm is somewhat slower than in Sound File 2.23, compatible with the use of QCF signals and the lower FME: the bat is probably further away from obstacles; the combination of structure and FME points to *Hypsugo savii* as the only option; level of confidence: certain.
- **Sound File 2.25**: Riverbank in a forested valley at dusk; variations in sonority sometimes weak, sometimes more clearly audible: mixed **flat-ended FM signals** and **QCF** signals depending on the phase of flight; zero beat at **32 kHz**; the bat is hunting very actively: the fast rhythm becomes closer to a pipistrelle's, the bat is taking full advantage of the temporary presence of clouds of insects at dusk; the combination of structure and FME points to *Hypsugo savii* as the only option; level of confidence: certain.
- **Sound File 2.26**: Near a lone building close to a street light attracting insects; several bats emitting on slightly different frequencies fly around and inside the halo; variations in sonority weak but present (especially the 'tick' indicating that the detector is tuned below the FME of the individuals concerned): **flat-ended FM sweeps**; at 43 s, an individual flies past emitting **QCF signals**; the detector is on **33 kHz**: the individuals

at 35 kHz produce the 'tick' sonority whereas the bat emitting QCF signals produces the sonority typical of QCF signals when the detector is tuned just under the FME ('chyek'), it is emitting at 34 kHz; the bats are hunting very actively; the combination of structure and FME points to *Hypsugo savii* as the only option; level of confidence: certain.

Sound File 2.27: Recently cut hay meadow close to a large oak tree; several individuals emitting on slightly different frequencies fly close to the tree; there are some variations in sonority, but not very marked: **flat-ended FM signals**; detector tuned on **39 kHz**; the bats are hunting actively, as indicated by the fast rhythm; the structure/FME combination suggests either *Pipistrellus kuhlii* or *P. nathusii*; the former is more likely because no QCF signal is perceptible, but the fast rhythm, suggesting a very inquisitive bat, could explain the recourse to flat-ended FM sweeps by *P. nathusii*; however, at 43 s, a bat passes by with a 'pwepp' sonority indicating that its FME is at least 1 to 2 kHz lower than 39 kHz, and since *P. nathusii* seldom drops under 39 kHz when using flat-ended FM sweeps, it follows that for this individual at least the species is *P. kuhlii*; level of confidence: certain.

Sound File 2.28: Recently cut hay meadow along a forest border; several bats emitting on slightly different frequencies are flying along the tree line; sonority is solely of the high-pitched 'plip' type, indicating that the detector is tuned at least 4 to 5 kHz above the bats' FME; the sonority is almost too liquid for a QCF signal, but no conclusion can be drawn because the detector is tuned too far from the zero beat: **flat-ended FM or QCF signals**; detector tuned on **44 kHz**; as the detector is not well tuned, the FME is probably under 40 kHz, but it is impossible to be more precise; the supposed structure/FME combination suggests either *Pipistrellus kuhlii* or *P. nathusii,* but these species cannot be told apart with this recording; hence the importance of finding a correct zero beat, without which the FME cannot be assessed and the information is lost.

Sound File 2.29: Street-lit village; rather uniform sonority, the muffled sound resembles the zero beat of a flat-ended FM signal, but there are few variations; some slight variations due to the Doppler effect when the bat flies away from the microphone (at 5 s, 12 s, 42 s, etc.) suffice to conclude with confidence: **flat-ended FM signals**; detector tuned on **37 kHz**; the structure/FME combination points to *Pipistrellus kuhlii*; *P. nathusii* is ruled out because the FME is too low; and moreover, the slow and irregular rhythm suggests passive search for scarce prey, while in such circumstances *P. nathusii* would almost certainly be using QCF signals; moreover, a 'scraping' sound (made up of brief emissions in very rapid succession) can be heard between 9 s and 10 s, which is a social call; in *P. nathusii*, social calls come out in heterodyne outputs as a double 'scraping', clearly different from this one; the species involved is therefore *P. kuhlii*; level of confidence: certain.

Sound File 2.30: Along a wide canal in an open landscape in Belgium; the bat makes long repeated runs above the water, which explains the stretches of silence between the sequences; several rich sonorities ('tick', 'tawp', pwepp' and 'plip' sounds); the sensation is close to that given by QCF signals (due to the duration of the signals): **flat-ended FM sweeps** with long QCF stretches; zero beat at **35 kHz** (FME slightly below that in the most intense signals); the combination of information (structure, FME, habitat and geographical location) points to *Myotis dasycneme* as the only possibility; level of confidence: certain. (recording by Marc Van de Sijpe, from his *Guide Sonore de la Plupart des Espèces Belges de Chauves-Souris*, 1999)

Sound File 2.31: Banks of a lake with nearby trees; rich sonorities with big variations ('chyek', 'pwap' and liquid 'plip' sounds): **QCF signals**; zero beat at **39 kHz**; the structure/FME combination makes *Pipistrellus nathusii* the only possibility; level of confidence: certain.

Sound File 2.32: Banks of a lake on an open jetty; the bat is hunting above the water; rich sonorities with big variations: **QCF signals**; zero beat at **38 kHz**; the bat is hunting (accelerations of the repetition rate indicating phases of approach and capture); the conjunction of structure and FME points to *Pipistrellus nathusii* as the only possibility; level of confidence: certain.

Sound File 2.33: Banks of a small lake close to a forest; several bats are hunting along the forest border; several different sonorities ('tick', 'tawp' and 'pwepp' sounds) clearly audible but not typical of QCF signals: **flat-ended FM signals**; zero beat at **45 kHz**; differences between the various FMEs and the tuned frequency of the detector are under 2 to 3 kHz; the structure/FME combination gives *Pipistrellus pipistrellus* as the sole possibility; level of confidence: certain.

Sound File 2.34: Riverbank bordering a forest; several bats are flying along the forest border; several sonorities ('tick', tawp', 'pwepp' and 'plip' sounds) clearly audible but not typical of QCF signals: **flat-ended FM signals**; zero beat at **45 kHz**; differences between the various FMEs and the tuned frequency of the detector are under 2 to 3 kHz, except for the 'plip' sounds, whose dry sonority indicates a difference exceeding 5 kHz; the first sonorities, as in Sound File 2.33, point to *Pipistrellus pipistrellus*; however, in the case of the 'plip' sounds, it is another pipistrelle emitting in the 38-40 kHz range, i.e. *P. kuhlii* or *P. nathusii*; it is not possible to proceed any further with this recording, but if the bat worker had had the reflex to tune his or her detector on these lower frequencies, he or she would have certainly been able to reach a conclusion. A final remark: the very last signals of the sequence are steep FM sweeps: probably a *Myotis*...

Sound File 2.35: Forest track; several bats in transit along this forest understorey corridor at dusk; variations in sonority, but not particularly marked: **flat-ended FM signals**; zero beat at **55 kHz**; the rhythm is very fast (owing to local habitat or species?), which is more suggestive of a small *Myotis* than of a pipistrelle;

this trait, in conjunction with the structure and FME, suggests *Miniopterus schreibersii*; level of confidence: probable (the high repetition rate makes *Pipistrellus pygmaeus* rather unlikely, but caution should preclude our considering this identification as absolutely certain).

Sound File 2.36: Open woodland; several bats are hunting under the trees; some variations in sonority, but not strongly marked: **flat-ended FM signals**; some very 'dry' signals (at around 6 s then 12 s) could be interpreted as steep FM sweeps, which they resemble, but it is difficult to draw conclusions since they appear in sequences during which the bat is approaching obstacles (suggested by the fast and, more importantly, increasing rhythm); zero beat at 52 kHz; marked disparities in intensity between signals within a passing individual's sequence (especially towards the end of the sequence, at around 60 s): this is quite typical of *Miniopterus schreibersii*, which often emits at a higher intensity than pipistrelles, the wavering intensity being produced by the bat turning its head from side to side as it is scanning; rhythm and intensity together exclude *P. pygmaeus*; level of confidence: certain.

Sound File 2.37: Multi-storey forest border; several bats are hunting, some close to the trees, some further away; some variations in sonority, but not particularly marked: **flat-ended FM signals** (one bat passing by at around 28 s produces a rather rich 'pwepp' sound indicating a narrower bandwidth closer to a QCF signal, a longer signal duration, and an FME 1 to 2 kHz lower – this particular individual is flying more in the open, hence the slower rhythm); zero beat at **51 kHz**; now and then one notices an unsteadiness in the intensity of the signals of a same passing individual; all these observations converge to identify a group of *Miniopterus schreibersii* flying at various distances from obstacles; level of confidence: certain.

Sound File 2.38: Small clearing; a few bats are hunting close to the forest border and a little further away; clearly audible variations in sonority: **flat-ended FM signals**; the variations in rhythm from one series of signals to the next, and the variations in intensity from one signal to the next, are characteristic; capture sequences are mostly of the usual duration, but one is particularly long, which is relatively common in this species; zero beat at **51 kHz**; *Mioniopterus schreibersii*; level of confidence: certain; towards the end, a long CF signal reveals the presence of a horseshoe bat, maybe a harmonic of *Rhinolophus euryale*.

Sound File 2.39: Riverbank close to a loosely wooded area and buildings, at dusk; several bats are flying close to the trees and further away; some variations in sonority, but not particularly marked: **flat-ended FM sweeps**; zero beat at **57 kHz**; rhythm compatible with hunting pipistrelles, without the typical 'bursts' of *Mioniopterus schreibersii*; the conjunction of signal structure, FME and rhythm points to *Pipistrellus pygmaeus* as the only possibility; level of confidence: certain.

Sound File 2.40: Urban environment, next to a street light; one individual is hunting close to the lit area between buildings; easily detected variations of sonority, with a level of richness midway between a flat-ended FM signal and a QCF signal, indicating a narrow bandwidth: **flat-ended FM-QCF signals**; zero beat at **28.5 kHz**; the waltz-like rhythm is typical, with signals in groups of three produced throughout the sequence, sometimes reiterated; the conjunction of structure, FME and rhythm points to *Eptesicus nilssonii* because the bandwidth is too narrow and the FME a little too high for *E. serotinus* foraging around street lights (the rhythm would also probably be different); a long capture phase at 90 s seems to concern the capture of a moth (see "Example 1: the sonar of the barbastelle", page 312); in this long sequence, the total absence of slightly off-frequency signals, typical of genus *Nyctalus*, rules out *Nyctalus leisleri*; level of confidence: certain.

Sound File 2.41: Urban environment, close to street lights; at least three bats are hunting near the lit area between buildings; variations in sonority present, but not as rich as in Sound File 2.40, in particular due to the slightly different frequencies emitted by the three individuals: the one heard around 2 min is a little above the zero beat, and the one at around 2 min 30 a little below: **flat-ended FM sweeps**; detector on **25 kHz**; the rhythm is typical, with intervals very irregular and a tendency to emit signals in twos throughout the sequence; the combination of structure, FME and rhythm points to *Eptesicus serotinus*; the bandwidth is too wide and the rhythm too irregular for *E. nilssonii*, and the total absence of slightly off-frequency signals, typical of genus *Nyctalus*, in such a long sequence, rules out *Nyctalus leisleri*; level of confidence: certain.

Sound File 2.42: Recently cut hay meadow surrounded by hedges; one bat is hunting 2 m above the ground at dusk; variations in sonority present, but not as rich as in Sound File 2.40: **flat-ended FM signals**; detector on **27 kHz**; the rhythm is regular, in keeping with the relatively high repetition rate of the signals (indicating active hunting); the combination of structure, FME and rhythm points to *Eptesicus serotinus* because, given the level of activity, the FME is too high for *V. murinus* and too low for *E. nilssonii*; the total absence of slightly off-frequency signals, typical of genus *Nyctalus*, rules out *Nyctalus leisleri*; level of confidence: certain.

Sound File 2.43: Forest border on a wet meadow after dark; two bats are hunting actively and fly to and fro along the forest border; variations in sonority present, but not as rich as in Sound File 2.40: **flat-ended FM sweeps**; detector tuned on **26 kHz**; the rhythm is fast but irregular, with the same tendency to emit signals in twos as in Sound File 2.41; *Eptesicus serotinus*; level of confidence: certain.

Sound File 2.43a: Banks of a pool with a few isolated trees; one bat is hunting at dusk along the bank, sometimes near sometimes far from the trees; the variations in sonority indicate **flat-ended FM signals**, with a zero beat at **22.8 kHz**; during slow-rhythm phases, the absence of alternating FMEs and structures rules out genus *Nyctalus*; since we are in western Spain (Sierra de Cazorla, Andalusia), *V. murinus* is excluded,

leaving the genus *Eptesicus*; the low frequency when the bat is hunting actively, and the fairly regular rhythm when it is cruising point to *Eptesicus isabellinus*; level of confidence: probable.

Sound File 2.43b: Loosely wooded slope with rocks; a few bats are hunting just above the canopy; the variations in sonority indicate **flat-ended FM signals**; the detector is on **23.7 kHz**; during the slow-rhythm phases, the absence of interspersed signals with different FME and structure rules out genus *Nyctalus*; *V. murinus* is also ruled out because we are in western Spain (Montfrague, Extremadura), and we are left with the genus *Eptesicus*; the low frequency when the bat is hunting actively, and the rhythm, with frequent emission of signals in threes, suggest a probable *Eptesicus isabellinus*.

Sound File 2.44: Bank of a lake circled by reed beds; one bat is hunting relatively high after dark; rich variations in sonority: **QCF signals**; detector tuned on **25 kHz**; the regular rhythm and moderate repetition rate (slower than in Sound File 2.40) suggest that the bat is hunting normally; the combination of structure, FME and rhythm points to *Vespertilio murinus* because the frequency is low, the bandwidth narrow and the repetition rate slow for an *Eptesicus serotinus* hunting actively; given the duration of the sequence, the total absence of slightly off-frequency signals, typical of genus *Nyctalus*, rules out *Nyctalus leisleri*; level of confidence: certain.

Sound File 2.45: Forest border on a wooded slope; one bat is flying relatively high after nightfall; rich variations in sonority: **QCF signals**; detector tuned on **24 kHz**; the rhythm is regular, and the rather slow repetition rate indicates leisurely hunting; the combination of structure, FME value and rhythm points to *Vespertilio murinus* because the FME is low and the bandwidth too narrow for a hunting *Eptesicus serotinus*; given the duration of the sequence, the absence of slightly off-frequency signals (typical of the genus *Nyctalus*) rules out *Nyctalus leisleri* (however, care should be taken not to interpret variations in intensity as variations of the FME, the difference in sonority from one signal to the next is here negligible when compared with noctule sequences); level of confidence: certain.

Sound File 2.46: Mountain turf next to a larch forest; two bats are hunting quite close to the forest border; rich variations in sonority: **QCF signals**; detector tuned on **24 kHz**; the rhythm remains relatively regular whatever the repetition rate, which varies depending on whether the bat is hunting actively or in transit (in the background); since the FME is low, the bandwidth narrow, the rhythm regular and the repetition rate slow for *Eptesicus serotinus,* the conjunction of structure, FME value and rhythm points to *Vespertilio murinus*; given the duration of the sequence, the absence of slightly off-frequency signals (typical of genus *Nyctalus*) rules out *Nyctalus leisleri* (however, care should be taken not to interpret variations in intensity as variations of the FME, the difference in sonority from one signal to the next is here negligible when compared with noctule sequences); level of confidence: certain.

Sound File 2.47: Emergence from roost in a peri-urban environment; three bats emerge from buildings and fly along them; sonorities typical of **flat-ended FM signals**; detector on **25 kHz**; rhythm fairly regular, typical of transit flights in an environment bordered with obstacles, with no capture sequence; the combination of structure, FME value and rhythm fails to single out a particular species, as is often the case when bats are flying (in transit or hunting) close to obstacles and therefore producing flat-ended FM signals; *Eptesicus/ Vespertilio/ Nyctalus* (but not *N. lasiopterus*).

Sound File 2.48: Cliff top above forest; some bats are flying high above the trees; rich variations of sonorities, with a mix of two types of signal ('chick'/'pop') that is unrelated to an approach phrase: **QCF signals** with alternating FMEs; detector on **25 kHz**; the rhythm tends to be irregular, often without the usual progressive rise in intensity at the beginning of the individual sequences: the sequences tend to irrupt suddenly; the conjunction of structure, FME, alternating FMEs and rhythm points to *Nyctalus leisleri*; level of confidence: certain.

Sound File 2.49: Forested valley; some bats are hunting high above the tree tops; rich variations of sonorities, with a mix of two types of signal ('chick'/'pop') that is unrelated to an approach phrase: **QCF signals** with alternating FMEs; some phases include a more uniform series of signals with no off-frequency signals (at about 30 s for example), when we can assume the bat is flying closer to the trees, skimming the canopy; detector tuned on **23 kHz**; the rhythm is rather irregular, often without the expected progressive rise in intensity at the beginning of the individual sequences: the sequences tend to irrupt suddenly; at around 70 s, a long capture phase in three stages is heard with no preliminary approach phase picked up, which is quite characteristic of the species (see one possible explanation for this in "The sudden irruption of Nyctalus leisleri sequences", page 326); the combination of structure, FME, alternating FMEs and rhythm points to *Nyctalus leisleri*; level of confidence: certain.

Sound File 2.50: Street-lit village; some bats are flying high above the buildings; rich variations of sonorities, with a mix of two types of signal ('chick'/'pop') that is unrelated to an approach phrase: **QCF signals** with alternating FMEs; detector on **24 kHz**; the rhythm is rather irregular, often without the expected progressive rise in intensity at the beginning of the individual sequences: the sequences tend to appear suddenly (the series of 4 signals with alternating FMEs – and therefore sonority – at 48 s is highly characteristic); the combination of structure, FME, alternating FMEs and rhythm points to *Nyctalus leisleri*; level of confidence: certain.

Sound File 2.51: Small lake in a forest; bats are hunting above the water at dusk; rich variations of sonorities, with a mix of two types of signal ('chick'/'pop') that is unrelated to an approach phrase: **QCF signals** with alternating FMEs; detector on **20 kHz**; the rhythm is fast and fairly regular, in keeping with the highly active hunting typical of early night-time; the conjunction of structure, FME, alternating FMEs and rhythm points to *Nyctalus noctula*; level of confidence: certain.

Sound File 2.52: Street-lit village; bats are hunting above the buildings in complete darkness; rich variations of sonorities, with a mix of two types of signal ('chick'/'pop') that is unrelated to an approach phrase: **QCF signals** with alternating FMEs; detector tuned on **20 kHz**; the rhythm is slow and fairly irregular, in keeping with a more relaxed hunting activity than in Sound File 2.51; structure, FME value, alternating FMEs and rhythm all converge on *Nyctalus noctula*; level of confidence: certain.

Sound File 2.53: Small lake in a forest; one bat is hunting above the water after nightfall; rich variations of sonorities, with a mix of two types of signal ('chick'/'pop') that is unrelated to an approach phrase: **QCF signals** with alternating FMEs; detector tuned on **20 kHz**; the rhythm is fairly regular, and slower than in Sound File 2.51; structure, FME value, alternating FMEs and rhythm, taken together, point to *Nyctalus noctula*; level of confidence: certain.

Sound File 2.54: Tree-planted park with urban lighting; bats are hunting high above and under the trees after nightfall; rich variations in sonority but different from one individual to the next: **QCF and flat-ended FM signals**; detector on **25 kHz**; three main types of sonority can be heard: 1) 'tawp' sounds when on the zero beat, with variations typical of flat-ended FM signals and a rhythm typical of *Eptesicus serotinus* (e.g. at 18-31 s and at 47-51 s), level of confidence: probable (the sequences are too few and too short to positively exclude a noctule flying close to vegetation, which sometimes adopts an irregular rhythm such as this one); 2) 'pwepp' sounds (FME just under 25 kHz) with a more regular rhythm and a relatively rich sonority indicating a narrower bandwidth; such signals can be emitted by any of the QCF signal species belonging to the genera *Eptesicus, Vespertilio* and *Nyctalus* (except *N. lasiopterus*) when flying close to obstacles; the identification cannot be taken any further (e.g. at 79-87 s); 3) high pitched and liquid 'plip' sounds indicating QCF signals with an FME 4 to 6 kHz below 25 kHz; variations in pitch from one signal to the next combined with an FME of approximately 20 kHz point to the genus *Nyctalus*, and more specifically to *Nyctalus noctula*; level of confidence: probable (because of imprecise estimation of the FME).

Sound File 2.55: Same sequence as the previous one, but with the detector tuned on **20 kHz**; the flat-ended FM sweeps come out as 'tick' sounds and the alternating FMEs of the QCF signals are now clearly audible, thus confirming the genus *Nyctalus*; *Nyctalus noctula*; level of confidence: certain.

Sound File 2.56: street-lit village; bats are flying high above the buildings after dark; rich variations of sonorities, with a mix of two types of signal ('chick'/'pop') that is unrelated to an approach phrase: **QCF signals** with alternating FMEs; detector on **13 kHz**; the rhythm is slow and very regular in spite of the hour, favourable for active hunting; the structure, FME value, alternating FMEs and rhythm converge on *Nyctalus lasiopterus*; level of confidence: certain.

Sound File 2.57: Small lake in a forest; one bat is hunting above the water at dusk; rich variations of sonorities, with a mix of two types of signal ('chick'/'pop') that is unrelated to an approach phrase: **QCF signals** with alternating FMEs; detector on **13 kHz**; the rhythm is slow and very regular in spite of the hour, usually conducive to active hunting; the conjunction of structure, FME value, alternating FMEs and rhythm points to *Nyctalus lasiopterus*; level of confidence: certain.

Sound File 2.58: forested river bank at the foot of a cliff; one bat is hunting along the cliff face after nightfall; no variations in sonority at first (in particular during approach phases, when bandwidth increases and signal duration becomes shorter), but clearly perceptible after 38 s: **flat-ended FM signals** (except the approach signals close to vegetation, which are FM sweeps) then **QCF signals** (at the end of the sequence, when the bat is leaving the cliff area); detector tuned on **14 kHz**: the zero beat is found during the first part of the sequence, and towards the end of the sequence the sounds become 'bubbly', indicating that the FME has dropped by about 2 kHz to about 12 kHz, when the bat is flying in the open; the rhythm is regular, in keeping with the intense activity; the combination of structure, FME values and rhythm points to a probable *Tadarida teniotis*; the FME is low for *Nyctalus lasiopterus* when the bat recedes into the distance (this species would not necessarily emit alternating FMEs in this behavioural context, but would have an FME at around 16-18 kHz); level of confidence: probable.

Sound File 2.59: Open environment (mountain turf and rocks on an alpine pass); one bat is hunting high up in wide circles, as suggested by the variations in intensity throughout the sequence; rich variations in sonority: **QCF signals**; detector on **9.5 kHz;** the rhythm is regular; the conjunction of structure and FME value points to *Tadarida teniotis*; level of confidence: certain.

Sound File 2.60: Patchy forest border; one bat is hunting between the trees and a small lake in regular to and fro sweeps; no variation in sonority: **steep FM signals**; detector on **49 kHz** (however, the output would be the same if it were tuned elsewhere within the 70 kHz frequency band swept by the signals within 3 ms, i.e. between 100 and 30 kHz); the rhythm is regular and the repetition rate fast; none of these features is species-specific since they are related to flying conditions and may change in a same individual; the fast repetition rate rules out the larger *Myotis* species and the barbastelle, and the moderate intensity rules

out long-eared bats, leaving us with all the smaller *Myotis* species; also, now and then, some passing short flat-ended FM signals (e.g. at 31 s and 64 s) with a 'pwepp' sound indicating an FME at around 45-47 kHz (2 to 4 kHz below the detector's frequency) point to *Pipistrellus pipistellus*; level of confidence: certain.

- **Sound File 2.61**: Forest stream; several bats are hunting; no variations in sonority in some sequences, but some in others: **steep and flat-ended FM signals**; detector tuned on **45 kHz**; *Myotis* sp. and *Pipistrellus pipistrellus;* level of confidence: certain.
- **Sound File 2.62**: Forest track; several bats are hunting or in transit; none of the sonorities typical of flat-ended FM signals can be heard: **steep FM sweeps**; repetition rate is highly variable and depends on what the bat is doing and how far it is from obstacles, but one can note a regular and relatively slow rhythm (for steep FM sweeps) on some cruising phases, fairly typical of both the larger *Myotis* species and the barbastelle; detector on **30 kHz**; *Myotis* sp. and/or *Barbastella barbastellus*.
- **Sound File 2.63**: When a barbastelle produces its characteristic emissions, regularly alternating narrowband signals with FMEs at 34 and 43 kHz, it is sometimes possible to identify it with the heterodyne detector if the variator is on 41-43 kHz. The 34 kHz signals remain audible, albeit very high-pitched, and the special rhythm of the alternating emission is characteristic of the species.
- **Sound File 2.64**: Street-lit village; the dull sonority is reminiscent of the zero beat of a flat-ended FM or QCF signal but there is no audible variation in sonority; one can sense that the signals are complex, as if made up of rapidly repeated elementary components; detector on **17 kHz**; the regularity of the rhythm corroborates the idea that these are **social calls**; the FME is midway between *P. kuhlii* and P. *pipistrellus*, and the fact that it is a simple trill rules out *P. nathusii*; the identification process cannot go beyond the pair *Pipistrellus kuhlii*/*Pipistrellus pipistrellus*.
- **Sound File 2.65**: Wide forest alley; the 'scraping' sonority is more like an Orthopteran's stridulation than a bat signal, but the intensity (as assessed in the field) is too high for this; one can sense that the signals are complex, as if they were made up of rapidly repeated elementary components (which they are); detector on **28 kHz**; the regularity of the rhythm confirms the idea that these are **social calls**; the high FME and the double trill (sometimes even triple or quadruple) together are diagnostic: *Pipistrellus nathusii*; level of confidence: certain.
- **Sound File 2.66**: Oak stand after darkness at the end of August; the signals are strong and long (giving the impression of being stretched out), and uttered at fairly regular intervals; a more complex trill can be heard at around 8 s; detector on **15 kHz**; the regularity of the rhythm and the wide spacing of the emissions support the idea that these are **social calls**; the FME at 15 kHz is more consistent with emissions of *Nyctalus noctula* (the simple social calls of *Nyctalus leisleri* tend to be emitted at 13 kHz); level of confidence: probable.