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Use of ultrasound detectors for bat studies in Europe: experiences from field identification, surveys, and monitoring

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Since 1978 we have used ultrasound detectors for field studies of European bat species and large scale mapping and monitoring in Denmark and Sweden. The method has revolutionized the field studies of bats with great possibilities and advantages. Most of the 31-32 European bat species can be identified with bat detectors, but in practical work a few species pairs may have to be lumped e.g. *Myotis mystacinus/brandtii*. The species are not equally easy to find and identify, and some may need considerable time to be identified. No single variable of bat sound can be used to separate all species, and identification is often based on a number of characters in combination. Both acoustic and visual clues are of importance. Analyses of recorded sounds are valuable but do not stand alone; it is important to gain as much information as possible on the spot from the total situation in the field. We use ultrasound detectors equipped with heterodyne and time expansion systems in combination. This combination has many advantages for instant identification as well as subsequent analysis.

Key words: ultrasound detectors, heterodyning, time expansion, divider, Chiroptera, field identification, surveys, monitoring, Europe.

INTRODUCTION

In 1978 we started to use ultrasound detectors for field studies on bats in Scandinavia and extended the investigations to middle and southern Europe, with the aim of understanding the niche separation including species specific flight, hunting behaviour and echolocation (Ahlén, 1980, 1981a, 1990; Baagøe, 1987, 1994). We have also used species identification with detectors for extensive species mappings in Sweden and Denmark (e.g. Ahlén, 1983, 1997b, 1998; Ahlén and de Jong, 1996; Baagøe, 1984, 1986, 1988, unpubl. Atlas of Danish bats) and also in other field research (e.g. Ahlén, 1983, 1997a; Rydell and Baagøe, 1996; de Jong and Ahlén, 1991). Especially in the beginning we built up our knowledge and experience by testing our identifications by catching bats, by photography, or by following bats of known species from the roost.

Until 1978 the general opinion among scientists was that bat activity could be monitored by the use of ultrasound detectors, but that species identification was not possible. This was partly due to the fact that only few bats were studied under natural conditions where they use their most characteristic sounds.

Now two decades later it is generally accepted that species identification is possible, at least to a high degree, provided that the appropriate techniques are used (preferably heterodyne system in combination with time expansion system). Today bat detectors have come into practical use on a relatively large scale (e.g., Limpens *et al.*, 1997; Ahlén, 1998; O´Farrell *et al.*, 1999, Baagøe, unpubl. Atlas of Danish bats), but there is still a surprising scepticism as to whether the technique is reliable enough to permit species identification, surveys of areas, and monitoring of populations on a practical scale (e.g. Vaughan *et al.*, 1997; Barclay, 1999).

To us the use of bat detectors in the field has been a revolution, and without it so much valuable potential knowledge of bat biology is neglected. Like all methods it is not without pitfalls, it needs self-criticism and self-testing. But we are fully convinced of its great possibilities and advantages. Our work on European bat faunas, which also aims at the production of a field guide for detector-based work, has not yet been finished, but we shall try here to sum up some of our main experiences, gained through more than twenty years in the field with bat detectors.

BACKGROUND AND METHODS

Today a number of different systems and detectors are available for the transformation of ultrasonic bat pulses. We started with the heterodyne system (QMC, London) and soon added the divider system (Andersen and Miller, 1977; Miller and Degn, 1981) for parallel use to secure frequency information for analysis. The divider system was further developed with amplitude information added to the transformed signals (Ahlén *et al.*, 1983), accompanied by systems for analysis of divider signals. When a time expansion system became available in 1985 (Ahlén and Pettersson, 1985; Pettersson, 1985, 1993, 1999; Ahlén, 1990), we found it superior to the divider system for instant identification in the field and also for subsequent analysis. With many European bats it is much more difficult to hear the pulse shape and other sound qualities from the divider system than from the time expansion which gives the human ear and brain 10x longer time to interpret the signals. For sound analysis the time expansion signals have high sound quality (minimum change from original signal) while the divider signals have lost parts of the information. The divider also has a relatively short detection range which limits its usefulness in the field. The time expansion system enables a much more sensitive reception of signals and thereby a much longer range e.g., for whispering bats. The most quiet whispering bat in Europe (*Plecotus auritus*) can, under optimal conditions, be heard up to about 20 m with this system. However, the divider has one clear advantage by continuously working in real time with a broad band system making it practical for automatic registration of activity, quickly passing commuting bats etc.

Today we apply ultrasound detectors equipped with both heterodyning and time expansion systems (Pettersson Elektronik AB, models D-980 and D-240). The D-980 model also contains a modern, high quality version of divider system. We use portable digital tape recorders for documentation and subsequent analysis, and visible light from portable and strong halogen spotlights for visual observation (Baagøe, 1987, 1996; Ahlén, 1990, 1993*b*). Sound analyses are made on computers using BatSound software (Pettersson Elektronik AB). The heterodyne system has the advantage of being sensitive for long range detection and the transformed sounds have high tonal and rhythmic qualities recognised by the human ear although impossible to analyse for frequencies. The time expansion system is excellent for analysis of recordings, but also for direct listening. Further it has the advantage of covering all frequencies, so it gives a reliable broadband scanning to hear if "something is in the air".

In the field the procedure is to move around searching the surroundings with the time expansion system on one channel/ear and the heterodyne system on the other, scanning the frequency scale up and down to cover all frequencies. When a bat is found it is followed as long as possible with the detector while recordings are made and comments given on the behaviour of the bat. In this process visual observation is important and the bat is either observed directly (if there is light enough) or with glimpses of the strong light to observe behaviour, size, colour etc.

Most bats are identified directly in the field, but it is sometimes necessary, or a good help, to analyse recorded bat sounds on the computer, e.g. to see differences in frequencies or rhythm (repetition rates). But we must stress that certain qualities are lost and others can just as easily be heard directly in the field or on the tape. For even if man is primarily a visual animal, with a tendency better to believe what he has seen than what he has heard, the human brain is still an excellent processor of sounds. From the music world we know that a person with a musical ear can distinguish complicated sounds and rhythms and furthermore, articulations and intonations that can not be reproduced on paper. From the same composer´s sheet different conductors can make their orchestra play the same music in different ways — with different articulations or intonations that cannot be read on the sheet of music. And others, musicians or the trained audience, can easily tell these differences. Another good example is the human voice heard on telephone; within a few seconds an individual person is recognised. The brain is computing sound information that is impossible or very difficult to measure or show on diagrams. Likewise we can separate qualities in the transformed bat sounds, also qualities that cannot (readily) be read on the different analysis diagrams.

Much more information is gained directly on the site and the total situation of the field observation is important — including also visual clues. This also underlines the importance to use detectors with highest possible sound quality (minimum change from original), even if this quality is not needed in computer analysis.

IDENTIFICATION OF SPECIES

Guidelines for detector identification of European bat species are given by Ahlén (1981*a*, 1990), Weid and Helversen (1987), Weid (1988), Zingg (1990), Limpens and Roschen (1995), and Barataud and Tupinier (1999). With increasing knowledge the method is constantly refined and there is a great need for new and detailed instructions.

Variation in Behaviour and Vocalisation

It is important to realise that unlike bird song the echolocation pulses of bats are used for orientation and vary within limits with the situation. Each bat species has a variety of behaviours when emerging from roosts, commuting, hunting insects in different habitats, swarming around roost entrances, etc. The sonar and other vocalisation vary accordingly. We have known for a long time that in several species, it is only in certain typical situations, that the sounds and behaviour are so species specific or characteristic that we can easily identify the species (Ahlén, 1980, 1981*a*, 1981*b*, 1990, 1993*a*; Baagøe, 1986, 1987, unpubl.).

Features for Identification

As it is often the case with morphological characters, no single variable of bat sound can be used to separate all bat species. Species identification must sometimes be based on differences of a number of characters in combination. Combinations of acoustic and visual clues are often useful. Visual observation can give information on e.g. size, colour, wing movements, and size of ear. Sounds can be analysed for frequencies, pulse shapes, and rhythm/repetition, but the human brain can also handle further tonal and rhythmic qualities that are impossible or difficult for computer analyses. Most acoustic identification is based on sonar, but in a few special cases social calls also include valuable, additional information.

Examples

Below we present a few examples of how variation in sound production and behaviour can affect the identification possibilities and how the observer can solve the problems. Other examples can be found in Ahlén (1990), and Limpens and Roschen (1995).

Vespertilio murinus — One of the most illustrative examples of the importance of choosing the right situation for easy identification is that of *V. murinus*. This species most often lives in the countryside in summer and moves in autumn into cities with big buildings, vertical rock walls, etc, where individuals gather and males perform a territorial song flight (Figs. 1-2). This goes on in the autumn evenings in front of the hibernation sites, e.g. in tall buildings where they hibernate (Ahlén, 1981*a*; Baagøe, 1991, In press *b*, unpubl.). This call, or song, is quite unique among European bats and easy to recognise. It is almost impossible to make a mistake if identification is based on this song.

The hunting sonar of this species is sometimes more difficult to recognise because there are at least 4 species that in some special situations are quite similar (*Eptesicus nilssonii*, *E. serotinus*, *Nyctalus noctula,* and *N. leisleri*). Especially when these four species are heard hunting close to street lamps or flying outside roosts there is a great variation in pulse repetition because of their manoeuvres and the pulse shape and frequency converge or vary so it is very easy to be confused. For all these four species their sonar is much more characteristic and species specific in ordinary hunting flight or when commuting. In such cases it becomes quite easy to hear the difference: *V. murinus*, with distinctly lower frequency than *E. nilssonii*, has a remarkably slow repetition, much slower than both *E. nilssonii* and *E. serotinus* (Ahlén, 1981*a*; Baagøe, In press *a*, In press *b*). The pulses are all the same and repeated regularly. *N. noctula* often uses alternating pulses of two types and has lower frequencies than the other species. *N. leisleri* is similar to *N. noctula* but has higher frequencies and faster repetition. Thus the echolocation does not cause any problem for the trained observer (Figs. 3 - 6). We always recommend the less trained observers to move away from street lamps with hunting bats or from the vicinity of roosts to wait for bats passing with more species specific sonar.

Pipistrellus nathusii and *P. pipistrellus* — The 55 kHz form of *P. pipistrellus* (suggested as new species *P. pygmaeus*, Jones and Barratt, 1999) does not cause any identification problem, but the 45 kHz form of *P. pipistrellus* (suggested to be *P. pipistrellus* sensu stricto) and *P. nathusii* are overlapping in frequency. However in search phase flight or when commuting *P. nathusii* uses slower repetition rates (intervals about 100 ms but also frequently of ca. 200 ms) than both phonic forms of *P. pipistrellus* (about 80 or 90 ms depending on pulse type —Ahlén, 1981*a*), and we can easily separate them by just listening to them with the detector (Fig. 7). However observation on the spot of what the bat is doing, helps ensure that in this case *P. nathusii* is not observed only in some complicated manoeuvre with a faster repetition rate and thus perhaps mistaken for *P. pipistrellus*.

Barbastella barbastellus —This species has different echolocation modes (Ahlén, 1981*a*, 1990): one where two different pulses are regularly alternating, and another mode where only one pulse type is used. The two pulses are usually at about 33 and 44 kHz respectively (with some variation) (Fig. 8). When *B. barbastellus* is using the alternating pulses, it is enough to hear one passing bat on time expansion to recognise the species. In this situation it is almost impossible to make a mistake. But when only using the low frequency pulse type the species is easily overlooked, because it can be taken for a *Myotis* sp. or perhaps a distant *E. nilssonii*. In such cases only well-trained and experienced observers will react on subtle tonal and rhythmic qualities and suspect that it could be a *B. barbastellus*, and a careful analysis of the pulses in a good recording with a sound analysis program is most often required to confirm whether the identification is correct.

Myotis dasycneme — Like *M. daubentonii* and *M. capaccinii*, *M. dasycneme* often hunts insects over the water surface of lakes and rivers. The FM-sweep pulses are much like other *Myotis* species and a quick observation does not always permit the observer to notice the slightly lower frequency at amplitude maximum (35 instead of 45 kHz) or the lower pulse repetition rate (average in straight flight 110 instead of 90 ms long intervals). Careful analysis of a good recording can reveal this, but in the field it is often difficult to be sure. However when flying over open water surfaces, *M dasycneme* now and then emits very strong CF-portions (or sometimes quasi-CF as defined by Kalko and Schnitzler, 1993) in the middle of the sweeps which is easily heard if heterodyning is tuned to 35 kHz, or better, with time expansion (Fig. 9). This is quite characteristic for *M. dasycneme* and enables instant and safe identification. The problem is that *M. dasycneme* can avoid this sound element entirely for periods and it is possible that they only use it in certain situations. However here visual clues are also helpful since *M. dasycneme* flying over water is easily recognised by its size when seen with a lamp.

Other *Myotis* species — A number of *Myotis* species with FM-sweeps are difficult to separate on echolocation sounds, but there are ways to identify most of them by looking at their size and colour or observing behavioural characteristics. For some of them it is necessary to study the bat closely for long time and only under very favourable conditions is an identification possible. In many situations especially during surveys and monitoring with limited time for each observation, it is necessary to lump them, especially the pairs *M. brandtii* and *M. mystacinus*, as well as *M. myotis* and *M. blythii*. Likewise *M. bechsteinii* can often be confused with species like *M. mystacinus* until it is possible to see and hear the very characteristic hunting behaviour (Ahlén, 1990; Baagøe, In press *c*). *Myotis nattereri* and *M. emarginatus* are possible to recognise for the trained observer with a strong light (Fig. 10).

These were some examples of the fact that bat echolocation sounds vary according to different situations and that the most species specific sounds must be sampled to make identification easy or even possible. This was discovered very early in our work, in fact already during 1978, and various aspects of this problem was mentioned or discussed in a number of papers e.g. Ahlén (1981*a*, 1983, 1985, 1990, 1993*a*); Baagøe (1986, 1987). The fact that echolocation recordings made outside roosts (Vaughan *et al.*, 1997) are difficult to identify in blind-tests by bat observers are just in line with our findings. However we do not agree that these observations justify the generally formulated conclusions about difficulties with identification of species, and that ultrasound detectors should not be used in survey work of geographical areas. Our argument is that reliable species identifications in the field must be carried out with knowledge about the variation in echolocation as indicated by the above examples.

SURVEYS AND MONITORING

Methods for surveys and monitoring must be standardized and repeatable. The bat species differ as to how easy they are to find and identify with detectors, and the observer is sometimes forced to use some time at one site to secure a safe identification. The fact that different species are detected at different ranges must also be taken into account. Already in the start of our work with ultrasound detectors we tested a number of different methods to survey areas for bats and to monitor their populations (e.g., Ahlén, 1980, 1981*a*, 1982, 1990; de Jong and Ahlén 1996). Further examples on monitoring bats in Europe are found e.g. in de Wijs (1999), Gjerde (1999), Harbusch (1999), Hollander (1999), and Masing (1999). The two main methods that we use today are measuring site species richness and securing quantitative data by line transects.

Site species richness

A number of sites (localities) are selected in an area or region. Each site is visited two or three times with optimal weather conditions during the nursery season, preferably towards the end of this period. The aim is to measure species richness of the site and the number of individuals is only roughly assessed. Since the effort is directed to find all species, the researcher must search all corners of the site for possible remaining undetected species. At least in Europe a skilled observer will find all species present in each site. Data from species mapping can give a good picture of the regional fauna, local species distributions and also habitat choice. If repeated over a number of years, these qualitative data can also be used as monitoring of all bat species of a region. Population changes that are difficult to detect by measuring population density can be obvious very early in reliable species richness mapping data, when species recolonise or disappear from sites.

Line transects

Bats are observed along a line and the species, number of individuals (estimated numbers if swarms), and place of observations are registered. This can be carried out by driving a car at standardised speed, e.g. 50 km/h, where the trip counter is reset at road-crosses, churches, bridges etc. and the observations are spoken into a pocket recorder. Line transects can also be designed with routes for walking, and also for the use of bicycle or boat. Line transects are used to collect quantitative data about populations and the efficiency varies with species. Especially the car version can give great amounts of data on a few abundant and easily identifiable species but almost nothing on rare species or on species that avoid roads. Species that are difficult to identify (see the examples above) have to be lumped or left unidentified with this method. Within each species, data can be used in index-calculations to analyse intraspecific variation e.g. to look for population changes over time or for comparison between areas.

Verification

We recommend bat observers to document records of rare species or species new to geographical areas by tape recordings of the sounds (time expansion and heterodyning) and careful notes on circumstances, behaviour, hunting methods, use of habitat, etc. With this documentation and some data on instruments used, earlier personal experience of the species in question and bats in general, it would in most cases be possible to evaluate the reliability of the identification. With many active bat observers, there will sooner or later be a need of rarities committees like in ornithology to handle regional or national reports.

SKILL AND RELIABILITY

Basically there is no difference between bird watching and bat watching, and performed with the necessary skill they are equally trustworthy. A bird watcher needs a good eyesight and a reasonably musical ear, a bat watcher needs a good musical ear and a good night vision. They both need training, "tuning", and self-criticism. Rather say: "I did not hear or see it well enough" - than guessing or wishful thinking. A person with an eyesight below average will find field ornithology too difficult to be an attractive occupation, whereas people with a good eyesight can learn to recognize even bird species with only minor differences in appearance. Likewise individual human beings have quite different abilities to learn to use sound, because of individual variation in musicality, absolute pitch, sense of rhythm, and sound memory. Those with a good ear quickly learn to distinguish the easy bat species by sound, and over time they can build up great skill in distinguishing also small differences in sound quality, rhythm and frequency. Most people have initial difficulties and need a couple of seasons of intensive field experience to build up enough skill to be able to work professionally with detector based surveys or monitoring. But there is a perhaps rather large group of people, who will never learn to use this technique, in spite of great effort, especially because their sound memory is not good enough. This is a problem, especially since this lack of "ear" cannot be fully compensated by recording the sounds and visualizing them on the computer screen. But it should not prevent those who can, from using the technique. The bat detector technique is just as objective as bird watching and documentation of rare observations are actually often easier to obtain with tape recordings. Self-testing is possible by comparison with others, by catches, observations near (but at a good distance from) colonies, and by photography. Especially when large groups of non-specialist naturalists are engaged in faunistic work, schemes for such training is essential as it has recently been successfully organized in the Netherlands (Limpens *et al.*, 1997).

CONCLUDING REMARKS

More than any other method, the use of ultrasound detectors has expanded the possibilities for field studies on bats, their geographical distribution, habitat choice and population dynamics. The method is efficient and reliable provided that the following three points are respected:
(1) sample species specific sequences for safe identification;
(2) use best available technique with high sound quality;
(3) a well developed sound memory and musical ear is a prerequisite for a skilful observation.

LITERATURE CITED

AHLÉN, I. 1980. Problems of bat identification on sounds. Biophon, 7(2): 12-l4.

AHLÉN, I. 1981*a*. Identification of Scandinavian bats by their sounds. Department of Wildlife Ecology, SLU. Report 6. 1-56.

AHLÉN, I. 198l*b*. Field identification of bats and survey methods based on sounds. Myotis, 18-19: 128-136.

AHLÉN, I. 1982. Survey methods for bats. Department of Wildlife Ecology, SLU. Report 9: 55-58. [In Swedish with English summary].

AHLÉN, I. 1983. The bat fauna of some isolated islands in Scandinavia. Oikos, 41: 352-358.

AHLÉN, I. 1985. Sonar signals used in census work and flight activity studies on bats. Pp. 15:1-21, *in* Air-borne animal sonar systems. Colloque International CNRS, Lyon 1985 (B. ESCUDIÉ and Y. BRAUD, eds.). Centre National de la Recherche Scientifique, Lyon, 514 pp.

AHLÉN, I. 1990. Identification of bats in flight. Swedish Society for Conservation of Nature, Stockholm, 50 pp.

AHLÉN, I. 1993a. Species Identification of Bats in Flight. Pp. 3-10, *in* Proceedings of the first European Bat detector Workshop (K. KAPTEYN, ed.). Netherlands Bat Research Foundation. Amsterdam, 128 pp.

AHLÉN, I. 1993b. Some remarks on Technical Equipment for Field Observations of Bats in Flight. Pp. 21-23, in Proceedings of the First European Bat Detector Workshop (K. KAPTEYN, ed.). Netherlands Bat Research Foundation, Amsterdam, 128 pp.

AHLÉN, I. 1997a. Migratory behaviour of bats at south Swedish coasts. Zeitschrift für Säugetierkunde, 62: 375-380.

AHLÉN, I. 1997b. Ölands fladdermusfauna. Länsstyrelsen Kalmar län, Meddelanden 1997(7): 1-26. [in Swedish: The bat fauna of Öland].

AHLÉN, I. 1998. Gotlands fladdermusfauna 1997. Länsstyrelsen i Gotlands län. Livsmiljöenheten, Report, 1998 (4): 1-11. [in Swedish: The Bat fauna of Gotland 1997].

AHLÉN, I., and J. DE JONG 1996. Upplands fladdermöss - Utbredning, täthet och populationsutveckling 1978-1995. Länsstyrelsen i Uppsala län. Länsstyrelsens meddelandeserie, 1996(8): 1-43. [in Swedish: The Bat in Uppland - distribution, density and population dynamics 1978-1995].

AHLÉN, I., and L. PETTERSSON. 1985. Improvements of portable systems for ultrasonic detection. Bat Research News, 26: 76.

AHLÉN, I., L. PETTERSSON, AND A. SVÄRDSTRÖM. 1983. An instrument for detecting bat and insect sounds. Myotis, 21-22: 82-88.

ANDERSEN, B. B., and L. A. MILLER. 1977. A portable ultrasonic detection system for reading bat cries in the field. Journal of Mammalogy, 58: 226-229.

BAAGØE, H. J., 1984. Bornholms flagermus. Fjælstaunijn, 8(2): 80-84. [in Danish: The Bats of Bornholm].

BAAGØE, H. J., 1986. Summer occurrence of *Vespertilio murinus* (LINNÉ 1758) and *Eptesicus serotinus* (SCHREBER, 1780) (Chiroptera, Mammalia) on Zealand, Denmark, based on records of roosts and registrations with bat detectors. Annalen des Naturhistorischen Museums, Wien, 88/89 B: 281-291.

BAAGØE, H. J., 1987. The Scandinavian bat fauna - adaptive wing morphology and free flight in the field. Pp. 57-74, *in* Recent Advances in the Study of Bats (M. B. FENTON, P. A. RACEY, and J. M. V. RAYNER, eds.). Cambridge Univ. Press, Cambridge, 470 pp.

BAAGØE, H. J., 1988. Effektive Methodenkombination für Fledermausstudien liefert neue Befunde. P. 39, *in* HECKENROTH, H., and B. POTT. Beiträge zum Fledermausschutz in Niedersachsen. Naturschutz Landschaftspfl. Niedersachs. 17, 78 pp. [in German: Efficient combination of methods for bat studies yield new possibilities].

BAAGØE, H. J. 1991. Flagermus. Pp. 47-89, *in* Danmarks Pattedyr (B. MUUS, ed.):, Vol. 1. Gyldendal, Copenhagen, 176 pp. [in Danish: Bats (in Mammals of Denmark)].

BAAGØE, H. 1994. A community of Michrochiroptera in an East African montane forest - diversity in flight strategies and habitat selection. Bat Research News, 35:15.

BAAGØE, H. 1996. Assessing species diversity of michrochiroptera. Pp. 57-59, *in* Biodiversity in Asia: Challenges and opportunities for the scientific community (J. A. MCNEELY and S. SOMCHEVITA, eds.) Office of Environmental Policy and Planning, Ministry of Sciencee, Technology, and Environment. Bangkok, 204 pp.

BAAGØE, H. J. In press *a*: *Eptesicus serotinus*. *In* Handbuch der Säugetiere Europas (F. KRAPP, ed.), vol 3. Chiroptera. AULA- Verlag, Wiesbaden.

BAAGØE, H. J. In press *b*: *Vespertilio murinus*. *In* Handbuch der Säugetiere Europas (F. KRAPP, ed.), vol 3. Chiroptera. AULA- Verlag, Wiesbaden.

BAAGØE, H. J. In press *c*: *Myotis bechsteinii*. *In* Handbuch der Säugetiere Europas (F. KRAPP, ed.), vol 3. Chiroptera. AULA- Verlag, Wiesbaden.

BARATAUD, M., and Y. TUPINIER. 1999. Ballades dans l´inaudible. Univers acoustiques des chiroptères d´Europe. Pp 7-20, *in* Proceedings of the 3rd European Bat Detector Workshop (C. HARBUSCH, ed.). Travaux Scientifiques du Musée National D´Histoire Naturelle de Luxembourg, 31, Luxembourg, 141 pp.

BARCLAY, R. M. 1999. Bats are not birds - a cautionary note on using echolocation calls to identify bats: A comment. Journal of Mammalogy, 80: 290-296.

DE JONG, J., and I. AHLÉN. 1991. Factors affecting the distribution pattern of bats in Uppland, central Sweden. Holarctic Ecology, 14: 92-96.

DE JONG, J and I. AHLÉN. 1996. Artantal och populationstäthet hos fladdermöss. *In* Handbok för miljöövervakning. Naturvårdsverket, Stockholm. (Internet publication).[in Swedish: Species richness and population density in bat populations].

DE WIJS, W. J. R. 1999. Feasibility of monitoring bats on transects with ultrasound detectors. Pp 95-105, in Proceedings of the 3rd European Bat Detector Workshop (C. HARBUSCH, ed.). Travaux Scientifiques du

Musée National D´Histoire Naturelle de Luxembourg, 31, Luxembourg, 141 pp.

GJERDE, L. 1999. Methods and theories of monitoring bats in Norway. Pp 73-86, *in* Proceedings of the 3rd European Bat Detector Workshop (C. HARBUSCH, ed.). Travaux Scientifiques du Musée National D´Histoire Naturelle de Luxembourg, 31, Luxembourg, 141 pp.

HARBUSCH, C. 1999. Monitoring bats in the Grand-Duchy of Luxembourg. Pp 59-79, *in* Proceedings of the 3rd European Bat Detector Workshop (C. HARBUSCH, ed.). Travaux Scientifiques du Musée National D´Histoire Naturelle de Luxembourg, 31, Luxembourg, 141 pp.

HOLLANDER, H., H. J. G. A. LIMPENS, and L. S. G. M. VERHEGGEN. 1999. Feasability of monitoring bats on transects with ultrasound detectors. Bat Research News, 35:26.

JONES, G., and E. M. BARRATT. 1999. *Vespertilio pipistrellus* Schreber, 1774 and *V. pygmaeus* Leach, 1825 (currently *Pipistrellus pipistrellus* and *P. pygmaeus*; Mammalia, Chiroptera): proposed designation of neotypes. Bulletin of Zoological Nomenclature, 56(3): 182-186.

KALKO, E. K. V., AND H.-U. SCHNITZLER, 1993. Plasticity in the echolocation signals of European pipistrelle bats in search flight: implications for habitat use and prey detection. Behavioral Ecology and Sociobiology, 33:415-428.

LIMPENS, H. and A. ROSCHEN 1995. Bestimmung der mitteleuropäischen Fledermausarten anhand ihrer Rufe. NABU-Umweltpyramide, Bremervörde, 48 pp.. [in German: Identification of Middle European Bats on their vocalisation].

LIMPENS, H., K. MOSTERT, and W. BONGERS (eds.). 1997. Atlas van de Nederlandse vleermuizen. KNNV Uitgeverij, Utrecht, 260 pp. [in Dutch with English summary]

MASING, M. 1999. Experience of bat monitoring with bat detectors in Estonia. Pp 51-58, *in* Proceedings of the 3rd European Bat Detector Workshop (C. HARBUSCH, ed.). Travaux Scientifiques du Musée National D´Histoire Naturelle de Luxembourg, 31, Luxembourg, 141 pp.

MILLER, L. A. and H. J. DEGN. 1981. The acoustic behaviour of four Vespertilionid bats studied in the field. Journal of Comparative Physiology, 142: 67-74.

O´FARRELL, C., W. L. GANNON, and B. MILLER. 1999. Confronting the dogma: a reply. Journal of Mammalogy, 80: 297-302.

PETTERSSON, L. 1985. An instrument for time expansion of ultrasonic signals. Uppsala university, Institute of Technology, Report 85134:1-5.

PETTERSSON, L. 1993. Ultrasounds detectors: Different techniques, purposes and methods. Pp. 11-19, *in* Proceedings of the first European Bat Detector Workshop (K. KAPTEYN, ed.). Netherlands Bat Research Foundation. Amsterdam, 128 pp.

PETTERSSON, L. 1999. Time expansion ultrasound detectors. Pp. 21-34, *in* Proceedings of the 3rd European Bat Detector Workshop (C. HARBUSCH, ed.). Luxembourg, 141 pp.

RYDELL, J. and H. J. BAAGØE.. 1996. Bats and streetlamps. Bats, (Bat Conservation International) 14(4): 11-13.

VAUGHAN, N., G. JONES, and S. HARRIS 1997. Identification of British bat species by multivariate analysis of echolocation call parameters. Bioacoustics, 7: 189-207.

WEID, R. 1988. Bestimmungshilfe für das Erkennen europäischer Fledermäuse - insbesondere anhand der Ortungsrufe. Schriftenreihe Bayerisches Landesamt für Umweltschutz, 81: 63-72. [in German: Instruction for identification of European Bats - especially on echolocation sounds]

WEID, R. and O. V. HELVERSEN 1987. Ortungsrufe Europäischer Fledermäuse beim Jagdflug im Freiland. Myotis, 25: 5-27. [in German with English summary].

ZINGG, P. E. 1990. Akustische Artidentifikation von Fledermäusen (Mammalia: Chiroptera) in der Schweiz. Revue Suisse de Zoologie, 97: 263-294.

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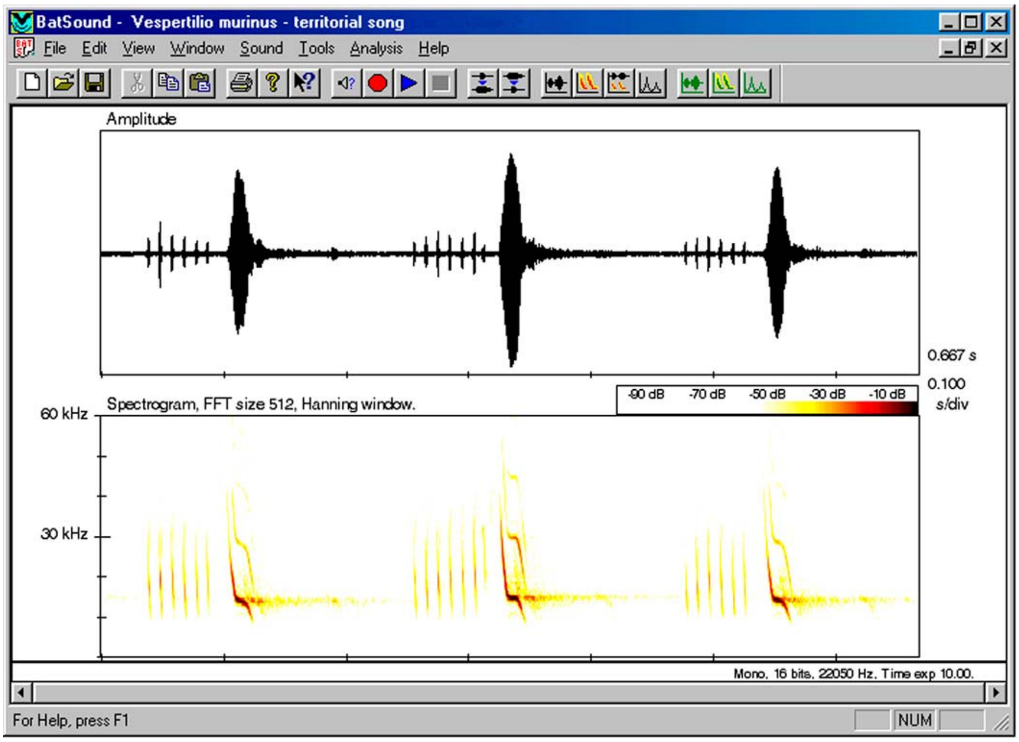

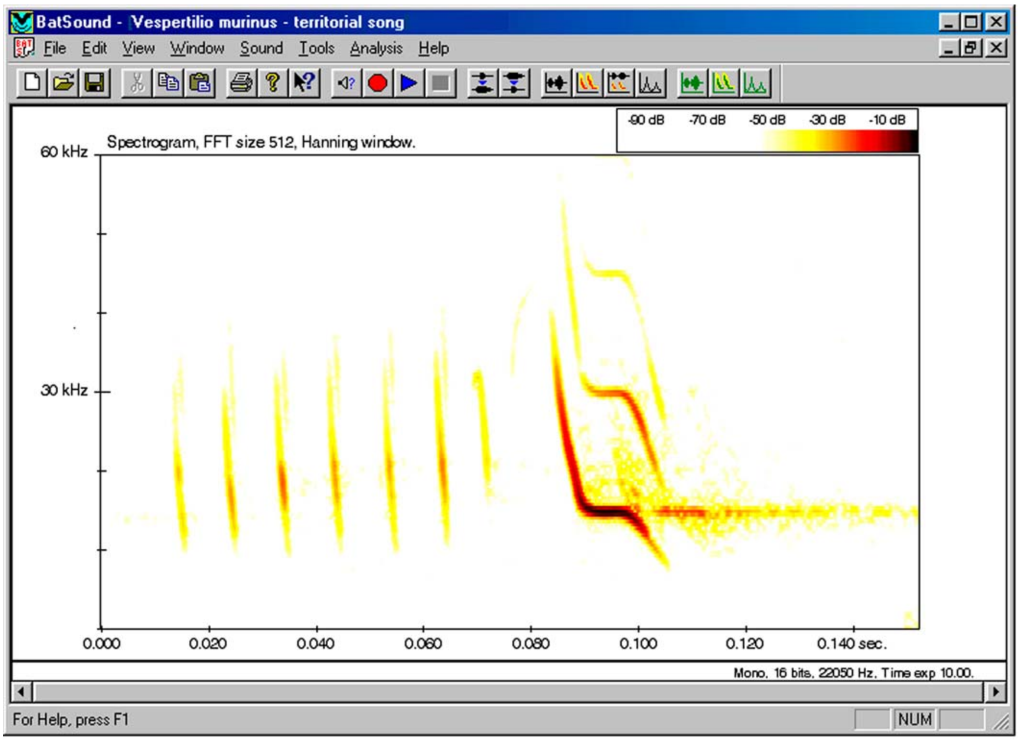

FIG. 1-2. Territorial song by male *Vespertilio murinus*. Repeated four times per second, this song is performed in flight during autumn evenings near tall city buildings and along vertical rock walls. It is a quite unique and unmistakable bat vocalisation which is audible by the naked ear but also heard over very long distance with detector. Taberg, Sweden, 1989 (IA).

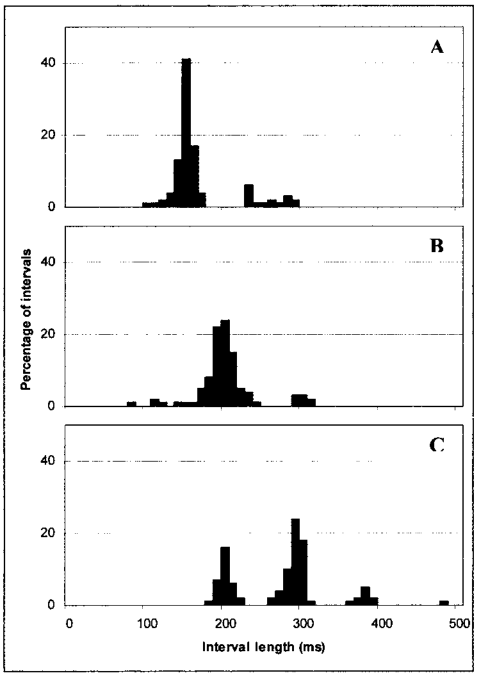

FIG. 3. Pulse intervals sampled from sonar of *Eptesicus serotinus* (A), *E. nilssonii* (B), and *Vespertilio murinus* (C) - all in ordinary hunting flight or commuting. Skåne and Öland, Sweden, 1997 (IA). Of these species *E. serotinus* is the only one always to use pulse intervals with a peak at 150 ms. This fast rhythm is easy to remember and recognize and it is quite different from the corresponding slower rhythm of *E. nilssonii* with a peak at 200 ms and frequently longer gaps (see also the characteristic frequency differences fig.5). *V. murinus* has a more powerful voice, but is much more variable than most other species. A species specific character for safe identification of *V. murinus* is the frequent occurrence of sequences of very slow and exactly regular pulse trains.

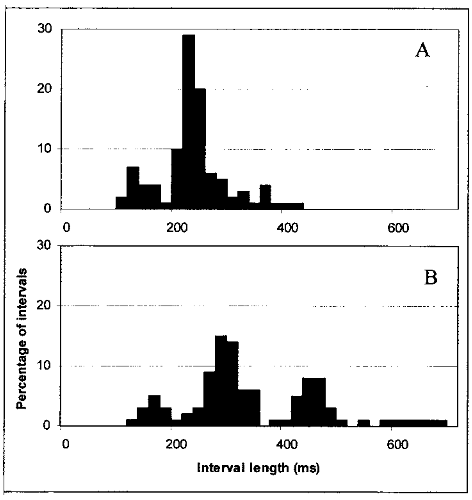

FIG. 4. Pulse intervals sampled from *Nyctalus leisleri* (A), and *N. noctula* (B) in open habitats. Intervals are variable but show distinct peaks. Enniscorthy, Ireland, 1997 and Fyledalen, Sweden, 1999 (IA and HJB).

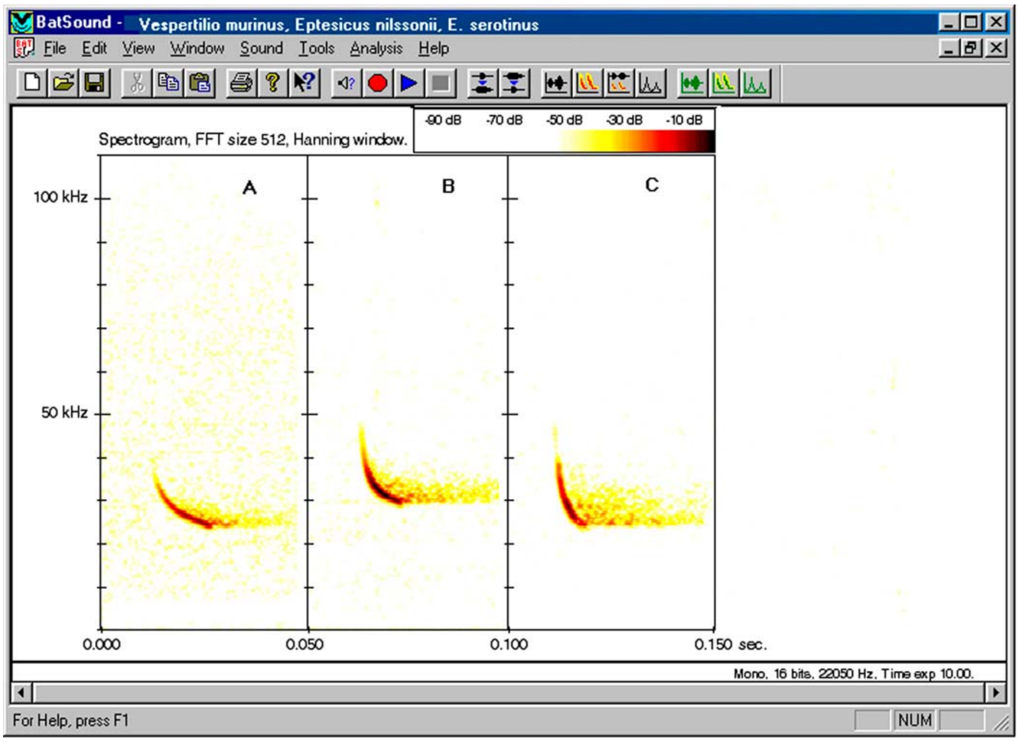

FIG. 5. Single pulses from echolocating *Vespertilio murinus* (A)*, Eptesicus nilssonii* (B), and *E. serotinus* (C). Important for identification is that *E. nilssonii* never goes down much lower than 30 kHz and that *E. serotinus* always goes down to 27-25 kHz. *V. murinus* varies the pulse shape more than the other species, but always ends at about 25 kHz. These characteristics are used in combination with the characteristic rhythms (fig.3). In *V. murinus* all pulses in a pulse train are all the same and separates it from the *Nyctalus* species (fig. 4) .

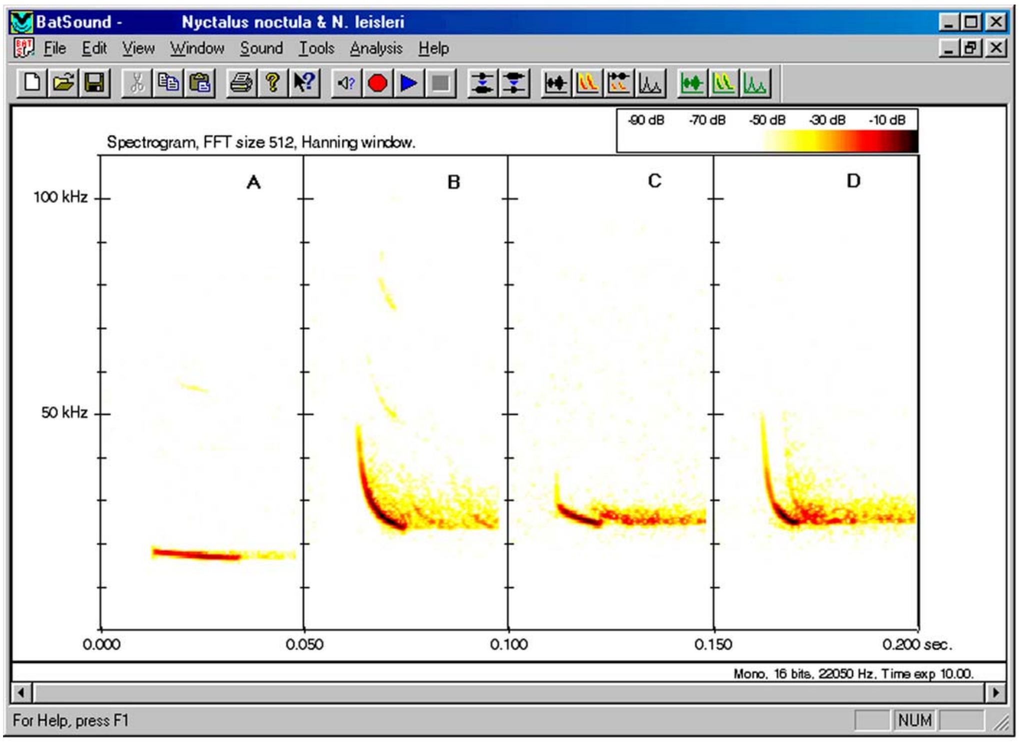

FIG. 6. The two different pulse types of *Nyctalus noctula* (A, B), and *N. leisleri* (C, D) sampled from bats using alternating pulses in the open, away from vegetation (heard as ´plip-plop´ through heterodyning). Note differences in frequency and pulse length. Fyledalen, Sweden, 1999 and Portumna, Ireland, 1997 (IA and HJB).

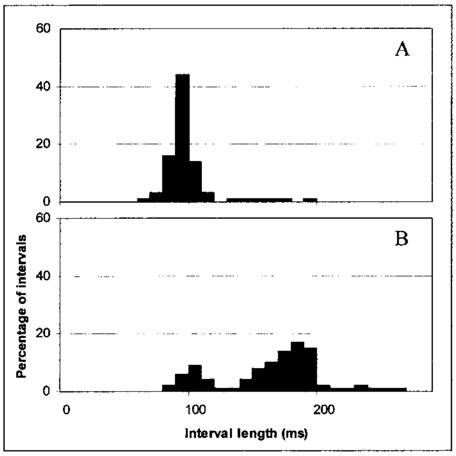

FIG. 7. Pulse intervals from *Pipistrellus pipistrellus* (45 kHz phonic form) (A) and *P. nathusii* (B) sampled at comparable situations in feeding habitats. *P. pipistrellus* is faster (intervals about 80 or 90 ms) and it avoids longer intervals. *P. nathusii* has a slower rhythm (short intervals about 100 ms) and is characteristic with the frequently used longer intervals about 200 ms). Sommersdorf, Germany, 1983 and Öland, Sweden, 1992 (IA and HJB).

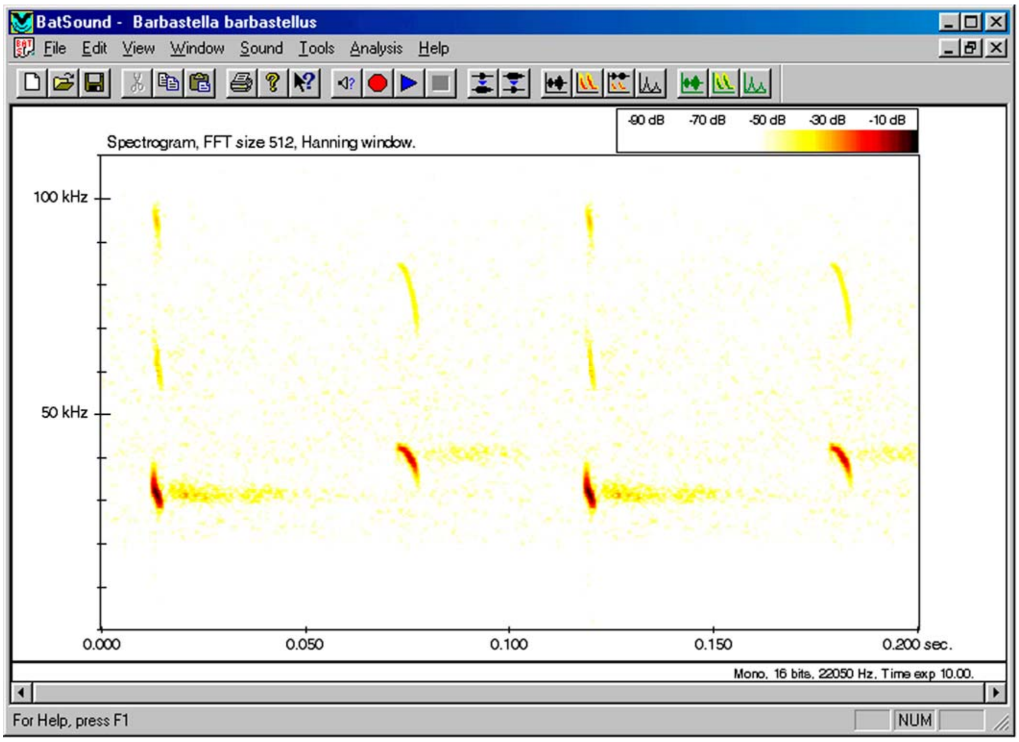

FIG. 8. The two pulse types normally used for echolocation by *Barbastella barbastellus*, a strong compact sweep or near-CF-pulse at about 33 kHz and a weaker sweep around 44 kHz . The regular alternation between these two pulses makes the bat unmistakable when heard through the time expansion system. When only the low frequency pulse is used it is very difficult to identify for the inexperienced bat observer. Vimmerby, Sweden, 1999 (IA).

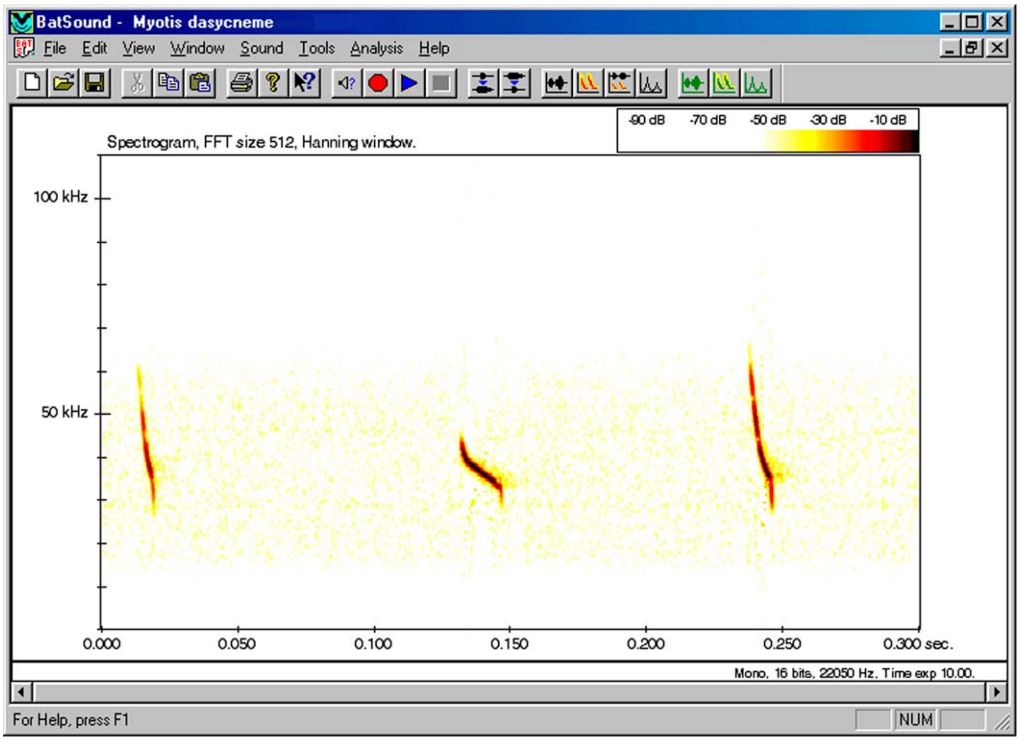

FIG. 9. A sequence of pulses from *Myotis dasycneme* flying over a lake surface. Now and then longer or shorter CF or quasi-CF parts are inserted in the middle of the pulse at about 35 kHz. This is very easy to hear with time expansion or with heterodyning if tuned correctly. Alauksta lake, Latvia, 1992 (IA).

FIG. 10. Multiflash photography (HJB) of *Myotis nattereri* hunting close to vegetation. Note the light, whitish grey underside (darker, yellowish grey in *M. emarginatus*).