# Inter- and intra-specific variability of social calls from native bat species

An English translation of the results
from the thesis of Dr. Guido Pfalzer


**Original title:** Inter- und intraspezifische Variabilität der Soziallaute heimischer Fledermausarten

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## Preface

15 years ago, the thesis of Guido Pfalzer called ‘Inter- and intra-specific variability of social calls from native bat species’ was published. This document constitutes a milestone for the field of bat echolocation, with the description of a wide diversity of social vocalisations from 16 European species recorded mostly in natural habitats. Many types of social calls were newly described and linked to behavioural contexts, enabling to unravel the specific functions of these calls.

Despite its broad interest to people, the dissemination of the knowledge contained in the thesis remained limited because the document is written in German. One scientific article extracted from the thesis was published in 2003 in the Journal of Zoology (PFALZER & KUSCH 2003)[1] but until now, many results and details of this work were only available to people speaking German.

In order to spread this comprehensive work, we decided to translate the results of the thesis into English. For each combination of species and social calls, you can now have access to the recording condition, the raw ultrasound values as well as the potential functions of the call. We hope this translation will fulfil different missions, including species identification based on social calls and a better understanding of bat behaviour based on ultrasound recordings. We also hope this translation will stimulate further research to document the vast array of bat social calls and functions.

Yann Gager, Leipzig, 26 April 2017

[1] **PFALZER, G. & J. KUSCH (2003):** Structure and variability of bat social calls: implications for specificity and individual recognition. – Journal of Zoology (2003) **261**: 21-33. London.

## Foreword

My research on bat social calls started in the last years of the old millennium. That was only a short time after the first pioneers studying bat echolocation calls in the field had to pull a handcart behind in order to move their recording equipment through the forest – sometimes, including a bulky high-speed tape recorder with the dimensions of a desk drawer and a 12 Volt truck battery for power supply. I was lucky not being reliant on that kind of "stone age" outfit already having an up-to-date time expansion detector and a handy DAT tape recorder at my disposal. Anyway, there was much "cable spaghetti" in the field and fresh batteries for replacement always had to be within reach. Fortunately, fieldwork is much easier today with enhanced technical equipment and automated computer analysis.

I take a little pride in the fact that after so many years the outcome of my investigations is still of interest and has lost none of its topicality. Even today, I occasionally receive enquiries from foreign countries. Among them are Austria, England, France, the Netherlands, Portugal, Switzerland and even Costa Rica and Australia. That is why in retrospect, I am amusedly looking back being at first dissatisfied with one of the evaluators grading of my thesis. This apparently occurred because of inability to realise the true value of the results presented. The fact that the Ph.D. thesis has sold in more than 200 copies by bookselling trade throughout Europe, which is quite unusual as I think, gives support to that point of view. By the way, the book is still available via Amazon - but the publisher recently has increased the price.

So much for advertisement. Of course, the presented data are rather incomplete, many native species have not even been examined or their social call repertoire is presented only in a fragmentary overview. The calls were sometimes recorded under "unnatural" conditions; for example using a hand-held specimen caught by mist netting. Finally, the naming of call types is more or less arbitrary, but you can call that "artistic licence". Nevertheless, the work remains the first attempt to document a vast variety of social calls from many native bats and provides valuable assistance with species identification. In addition, you can find in the original publication 250 pages of useful information about tree hole mapping, individual call variants, behavioural observations in the context of social call emission and much more that would go beyond the scope of this translation.

I would like to thank Jürgen Kusch†, who did most of the work to realise the publication in the Journal of Zoology, channelling a way to arouse international interest. Furthermore, sincere thanks go to Yann Gager and his colleagues from France and Belgium, who now had the idea to translate parts of my thesis into English. The research on bat social calls gave a lot of pleasure to me. Unfortunately, I am no longer doing research. However, I hope that the translation may encourage some bat specialists to continue this work by collecting additional data on social calls in order to generate an operational reference document for precise species identification.

Guido Pfalzer, Kaiserslautern – Mölschbach, 27 March 2017

**Abbreviations:**

FM: Frequency-modulated

(Q)CF: (Quasi-) Constant-frequency

FFT: Fast Fourier Transform

$F_{max}$: Peak frequency

$F_{start}$: Start frequency or maximum frequency (= highest frequency of the call)

$F_{end}$: End frequency or minimum frequency (= lowest frequency of the call)

## 5.2 Social calls in flight and in roosts – Call types and their variability

Social calls from 15 free-ranging bat species belonging to five genera were recorded between May 1998 and October 2000. The recordings contain a total of 685 hours of call sequences from various roosts, mating and foraging grounds stored on DAT tapes. As table 5.2.1 shows, eight species were recorded on foraging grounds or during the mating flight and social calls from 13 species were documented in or at the roost. The social calls from a 16$^{th}$ bat species originate from a Northern bat (*Eptesicus nilssonii*), which had been found injured and was handed over to the author in July 2001.

Seven out of 16 bat species were recorded in, or at, their maternity colonies. The social calls from seven species were documented during the mating season and at foraging grounds. In addition, social calls from seven bat species were recorded during mist netting, monitoring of batboxes, and from injured captive specimens. Table 5.2.2 shows the situations in which the social calls of the different species were recorded.

Further information on the study sites of foragings grounds, underground roosts, buildings and bat boxes can be found in Chapters 3.2 and 3.3.

**Table 5.2.1:** Compilation of the recording sites where social calls from 15 species were recorded.

| Bat species [1] | | Calls in flight | Calls in/at the roost | | | |
|---|---|---|---|---|---|---|
| | | | building roost (attics, cracks) | underground roost (mines, tunnels) | bat boxes | tree roosts |
| **Genus *Myotis*** | | | | | | |
| Daubenton's bat | (*Myotis daubentonii*, KUHL, 1817) | ● | | ● | ● | |
| Pond bat | (*M. dasycneme,* BOIE, 1825) | | | ● | | |
| Brandt's bat | (*M. brandtii*, EVERSMANN, 1845) | | | | ● | |
| Whiskered bat | (*M. mystacinus*, KUHL, 1817) | | | ● | | |
| Natterer's bat | (*M. nattereri*, KUHL, 1817) | | | | ● | |
| Bechstein's bat | (*M. bechsteinii*, KUHL, 1817) | | | | ● | |
| Greater mouse-eared bat | (*M. myotis*, BORKHAUSEN, 1797) | | ● | ● | ● | |
| **Genus *Nyctalus*** | | | | | | |
| Noctule | (*Nyctalus noctula*, SCHREBER, 1774) | ● | | | | ● |
| Lesser Noctule | (*N. leisleri*, KUHL, 1817) | ● | | | ● | ● |
| **Genus *Eptesicus*** | | | | | | |
| Serotine | (*Eptesicus serotinus*, SCHREBER, 1774) | | ● | | | |
| **Genus *Vespertilio*** | | | | | | |
| Particoloured bat | (*Vespertilio murinus*, LINNAEUS, 1758) | ● | ●[2] | | | |
| **Genus *Pipistrellus*** | | | | | | |
| Common Pipistrelle | (*Pipistrellus pipistrellus*, SCHREBER, 1774) | ● | ● | | | |
| Soprano Pipistrelle | (*P. pygmaeus*, LEACH, 1825) | ● | | | | |
| Nathusius' Pipistrelle | (*P. nathusii*, KEYSERLING & BLASIUS, | ● | | | ● | |
| Kuhl's Pipistrelle | (*P. kuhlii*, KUHL, 1817) | ● | | | | |
| **Total** | | **8** | **4** | **4** | **7** | **2** |
| | | | **13** | | | |

[1] Naming according to the specifications of the International Committee on Zoological Nomenclature (ICZN) (see LINA 1998)

[2] Roost suspected

**Table 5.2.2:** Compilation of the situations where social calls from 16 bat species were recorded (*) other recordings from mist netting, monitoring bat boxes or injured bats in captivity)

| **Bat species** [1] | | Calls at maternity colonies | Calls at the mating roost or territory | Calls at the foraging grounds | Other recording situations *) |
|---|---|---|---|---|---|
| **Genus *Myotis*** | | | | | |
| Daubenton's bat | (*Myotis daubentonii*, KUHL, 1817) | | | ● | ● |
| Pond bat | (*M. dasycneme,* BOIE, 1825) | | | | ● |
| Brandt's bat | (*M. brandtii*, EVERSMANN, 1845) | ● | | | |
| Whiskered bat | (*M. mystacinus*, KUHL, 1817) | | | | ● |
| Natterer's bat | (*M. nattereri*, KUHL, 1817) | ● | | | |
| Bechstein's bat | (*M. bechsteinii*, KUHL, 1817) | ● | | | |
| Greater mouse-eared bat | (*M. myotis*, BORKHAUSEN, 1797) | ● | ● | | ● |
| **Genus *Nyctalus*** | | | | | |
| Noctule | (*Nyctalus noctula*, SCHREBER, 1774) | | ● | ● | |
| Lesser Noctule | (*N. leisleri*, KUHL, 1817) | ● | ● | ● | ● |
| **Genus *Eptesicus*** | | | | | |
| Serotine | (*Eptesicus serotinus*, SCHREBER, 1774) | ● | | | |
| Northern bat | (*E. nilssonii*, KEYSERLING & BLASIUS, 1839) | | | | ● |
| **Genus *Vespertilio*** | | | | | |
| Particoloured bat | (*Vespertilio murinus*, LINNAEUS, 1758) | | ● | | |
| **Genus *Pipistrellus*** | | | | | |
| Common Pipistrelle | (*Pipistrellus pipistrellus*, SCHREBER, 1774) | ● | ● | ● | ● |
| Soprano Pipistrelle | (*P. pygmaeus*, LEACH, 1825) | | ● | ● | |
| Nathusius' Pipistrelle | (*P. nathusii*, KEYSERLING & BLASIUS, 1839) | | ● | ● | |
| Kuhl's Pipistrelle | (*P. kuhlii*, KUHL, 1817) | | | ● | |
| **Total** | **16** | **7** | **7** | **7** | **7** |

[1] Naming according to the specifications of the International Committee on Zoological Nomenclature (ICZN) (see LINA 1998)

### 5.2.1 Social calls from 16 bat species

In order to document the inter- and intra-specific variability of social calls from 16 bat species, a total of 1,068 individual time-expanded sequences were evaluated. 5,412 selected calls were measured by means of sound analysis software (Voxscope Professional, Avisoft Berlin) and 78 call types were defined (see Chapter 2.4). In the following chapters the characteristics of social calls, including sonograms and statistic parameters, are presented for each of the studied bat species. This listing is a first attempt to present the social call repertoire of the major part of the native bat community, but it raises no claim of completeness.

## 5.2.1.1 Daubenton's bat (*Myotis daubentonii*, Kuhl, 1817)

The social calls of Daubenton's bat recorded at the stretches of water Vogelwoog (KL 3) and Gelterswoog (S 1) as well as around batboxes near Harthausen can be classified in four types of calls.

#### A) Daubenton's bat (*M. daubentonii*): Call type A

We could register this type of call at Vogelwoog and Gelterswoog, mainly between April and July. Its sonogram looks like a "walking stick" (VICINUS 1997). In contrast to echolocation calls, the beginning of the call is initially modulated ascending (from deep to high frequencies). After a constant-frequency center part, the end of the call shows the modulation from high to low frequencies, which is typical for echolocation calls. Due to the inserted CF part, the calls are unusually long with a duration of approximately 10 ms (Tab. 5.2.1.1 a) and receive significantly more sound quality in the detector than the echolocation calls. In general, this type of call is integrated into normal echolocation call sequences, with fluent transitions being observed (Fig. 5.2.1.1 a).

**Table 5.2.1.1 a:** Statistical parameters of the call type A from Daubenton's bat (*M. daubentonii*)

| | Duration [ms] | $F_{max}$ [kHz] | $F_{start}$ [kHz] | $F_{end}$ [kHz] |
|---|---|---|---|---|
| Sample size | 69 | 69 | 69 | 69 |
| **Median** | **9,900** | **42,205** | **47,373** | **26,701** |
| Minimum | 7,500 | 33,161 | 34,884 | 19,811 |
| Maximum | 16,300 | 55,125 | 56,848 | 33,161 |
| Lower quartile | 9,000 | 40,052 | 43,497 | 25,409 |
| Upper quartile | 12,200 | 46,512 | 52,110 | 28,424 |
| **Average** | **10,383** | **43,285** | **47,423** | **26,782** |
| Standard deviation | 2,016 | 4,797 | 5,378 | 2,617 |

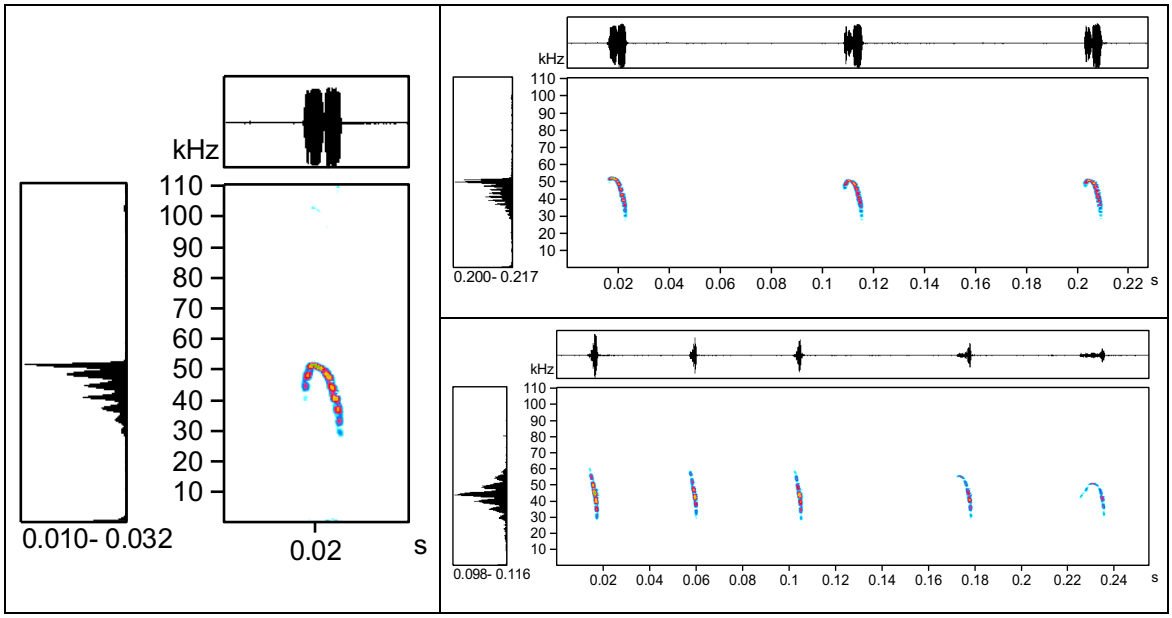


**Fig. 5.2.1.1 a:** "Walking stick" (Call type A) from *M. daubentonii* (Left and upper right: Vogelwoog, 31 May 2000, 22:57; Right below: recorded sequence with "walking stick call" fluently deriving from "normal" echolocation calls, Gelterswoog, 13 June 2000, 22:18)

## B) Daubenton's bat (*M. daubentonii*): Call type B

Ten social calls of this call type were recorded around batboxes near Harthausen and at Kaiserslautern Vogelwoog. The calls were integrated into ordinary echolocation call sequences. A flattening of the frequency modulation can be observed at the end of the call, resulting in a QCF structure (Fig. 5.2.1.1 b). The relatively long calls show an $F_{max}$ of around 34 kHz with end frequencies down to 16 kHz (Tab. 5.2.1.1 b), whereby they partly reach the frequency range audible to humans. The call type was emitted exclusively when several individuals were present at the same time.

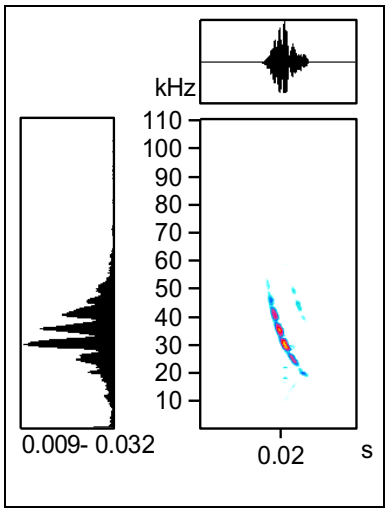


**Fig. 5.2.1.1 b:** Social call of *M. daubentonii* (Call type B) on the south shore of Vogelwoog (9 July 1999, 22:47)

**Table 5.2.1.1 b:** Statistical parameters of the call type B from Daubenton's bat (*M. daubentonii*)

| | Duration [ms] | $F_{max}$ [kHz] | $F_{start}$ [kHz] | $F_{end}$ [kHz] |
|---|---|---|---|---|
| Sample size | 10 | 10 | 10 | 10 |
| **Median** | **16,550** | **34,238** | **59,001** | **20,241** |
| Minimum | 9,600 | 29,716 | 52,541 | 15,935 |
| Maximum | 19,700 | 35,745 | 71,060 | 23,256 |
| Lower quartile | 12,200 | 31,869 | 53,402 | 17,227 |
| Upper quartile | 19,200 | 34,453 | 62,877 | 21,964 |
| **Average** | **15,880** | **33,290** | **59,733** | **19,768** |
| Standard deviation | 3,645 | 1,948 | 6,525 | 2,651 |

## C) Daubenton's bat (*M. daubentonii*): Call type C

Only one sequence with three single calls from this type (Fig. & Tab. 5.2.1.1 c) was recorded as one Daubenton's bat was illuminated by torchlight on its flight path nearby Vogelwoog returning to its roost. The bright belly of the animal was clearly visible. The calls are similar to the "walking stick call" of the call type A.

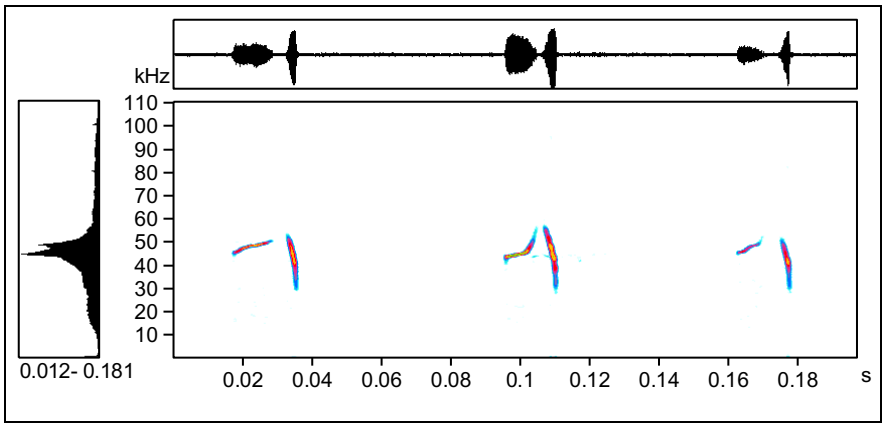


**Fig. 5.2.1.1 c:** Call of *M. daubentonii* (Call type C) on its flight path nearby Vogelwoog after the animal was illuminated by torchlight (31 May 2000, 22:52)

**Table 5.2.1.1 c:** Statistical parameters of the call type C from Daubenton's bat (*M. daubentonii*)

| | Duration [ms] | $F_{max}$ [kHz] | $F_{start}$ [kHz] | $F_{end}$ [kHz] |
|---|---|---|---|---|
| Sample size | 3 | 3 | 3 | 3 |
| **Median** | **17,567** | **46,081** | **57,135** | **26,558** |
| Minimum | 16,500 | 44,358 | 53,402 | 26,271 |
| Maximum | 19,700 | 48,234 | 62,877 | 27,132 |
| Lower quartile | - | - | - | - |
| Upper quartile | - | - | - | - |
| **Average** | **16,500** | **45,650** | **55,125** | **26,271** |
| Standard deviation | 1,848 | 1,974 | 5,047 | 0,497 |

## D) Daubenton's bat (*M. daubentonii*): Call type D

These calls from a hand-helt Daubenton's bat were recorded during mist netting at a basalt mine nearby Mendig. The calls are composed of several steeply frequency-modulated elements succeeding at an interval of approximately 6.5 ms (Fig. 5.2.1.1 d). Since the end frequencies are partly in the audible range (Tab. 5.2.1.1 d), the calls can also be perceived as chirping sounds without a detector.

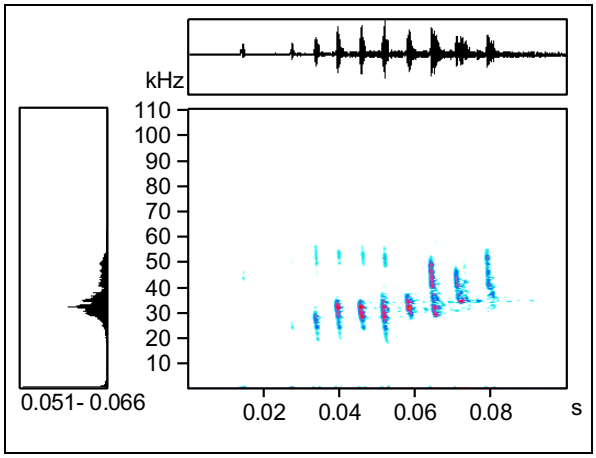


**Fig. 5.2.1.1 d:** Call of a hand-held *M. daubentonii* (Call type D) being trapped in a mist net nearby Mendig (21 August 1998, 21:15)

**Tab. 5.2.1.1 d:** Statistical parameters of the call type D from Daubenton's bat (*M. daubentonii*)

| | Duration [ms] | $F_{max}$ [kHz] | $F_{start}$ [kHz] | $F_{end}$ [kHz] | Pulse interval [ms] |
|---|---|---|---|---|---|
| Sample size | 2 | 2 | 2 | 2 | 16 |
| **Median** | **53,950** | **31,869** | **56,848** | **17,011** | **6,400** |
| Minimum | 52,800 | 31,869 | 53,402 | 16,796 | 5,800 |
| Maximum | 55,100 | 31,869 | 60,293 | 17,227 | 7,800 |
| Lower quartile | - | - | - | - | 6,250 |
| Upper quartile | - | - | - | - | 6,700 |
| **Average** | **53,950** | **31,869** | **56,848** | **17,011** | **6,506** |
| Standard deviation | 1,626 | 0,000 | 4,872 | 0,305 | 0,443 |

## 5.2.1.2 Pond bat (*Myotis dasycneme*, BOIE, 1825)

Calls of the Pond bat (*M. dasycneme*) were registered during mist netting nearby Mending, as an animal flew straight into the net.

### A) Pond bat (*M. dasycneme*): Call type A

The call (Fig. 5.2.1.2 a) is similar to call type D from Daubenton's bat but intervals of the FM pulses are approximately 3.5 ms longer in median (Tab. 5.2.1.2 a).

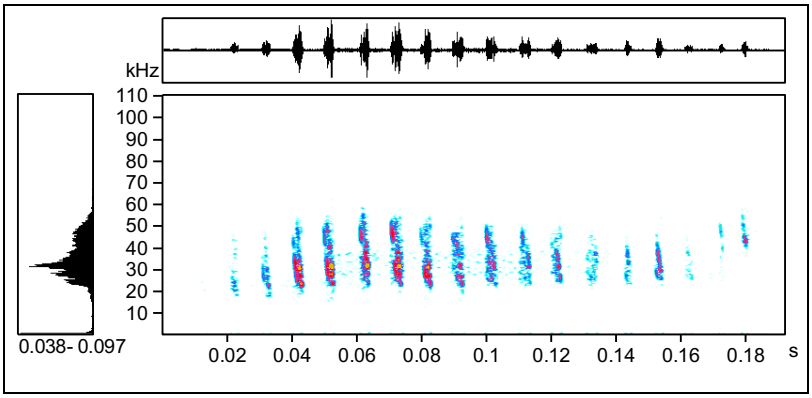


**Fig. 5.2.1.2 a:** Call type A from a Pond bat (*M. dasycneme*) being trapped in a mist net nearby Mendig (21 August 1998, 21:02)

**Tab. 5.2.1.2 a:** Statistical parameters of call type A from the Pond bat (*M. dasycneme*)

| | Duration [ms] | $F_{max}$ [kHz] | $F_{start}$ [kHz] | $F_{end}$ [kHz] | Pulse interval [ms] |
|---|---|---|---|---|---|
| Sample size | 3 | 3 | 3 | 3 | 20 |
| **Median** | **65,000** | **31,439** | **57,278** | **18,949** | **9,900** |
| Minimum | 46,700 | 31,008 | 55,986 | 16,796 | 9,000 |
| Maximum | 144,000 | 35,315 | 58,570 | 20,241 | 11,300 |
| Lower quartile | - | - | - | - | 9,600 |
| Upper quartile | - | - | - | - | 10,300 |
| **Average** | **85,233** | **32,587** | **57,278** | **18,662** | **10,025** |
| Standard deviation | 51,709 | 2,372 | 1,292 | 1,741 | 0,654 |

## 5.2.1.3 Brandt's bat (*Myotis brandtii*, EVERSMANN, 1845)

All social calls from Brandt's bat examined in this work were recorded around bat boxes nearby Dannenfels on the night of the 1st of July 2000. A total of six call types can be distinguished.

### A) Brandt's bat (*M. brandtii*): Call type A

Altogether 315 individual calls were assigned to this call type. These highly variable sounds consist of a high frequency FM modulated pulse from high to low frequencies, which usually flattens at the end and concludes in a CF structure or, in turn, transitions into an FM section modulated from low to high frequencies (Fig. 5.2.1.3 a). The individual calls are usually emitted in series with intermissions of about 90 ms (Tab. 5.2.1.3 a). Calls at a bat box with flightless juveniles were already emitted before the evening emergence of adult females. The call activity was most intense while older animals were swarming in front of the roost.

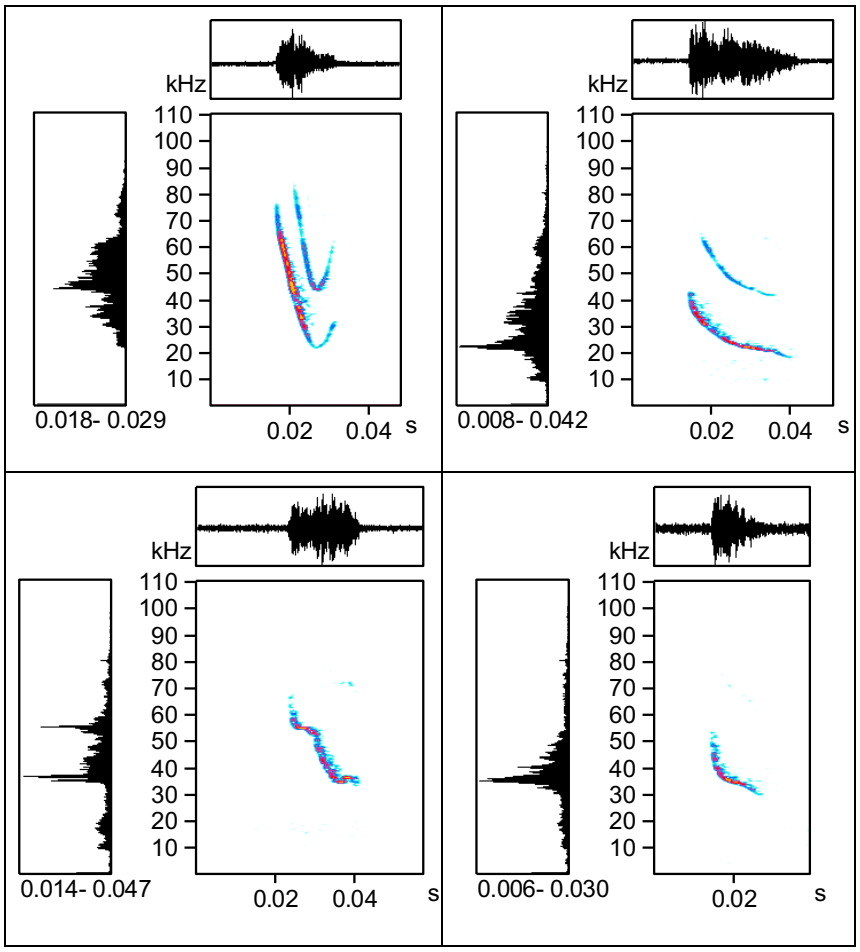


**Fig. 5.2.1.3 a:** Different variants of the call type A from Brandt's bat (*M. brandtii*) at a bat box nearby Dannenfels (1 July 2000, from 23:21 to 23:30)

**Tab. 5.2.1.3 a:** Statistical parameters of call type A from Brandt's bat (*M. brandtii*)

| | Duration [ms] | $F_{max}$ [kHz] | $F_{start}$ [kHz] | $F_{end}$ [kHz] | Call pauses [ms] |
|---|---|---|---|---|---|
| Sample size | 315 | 315 | 315 | 315 | 97 |
| **Median** | **17,700** | **35,745** | **69,768** | **20,672** | **88,800** |
| Minimum | 7,000 | 20,241 | 36,176 | 13,351 | 50,800 |
| Maximum | 43,000 | 56,848 | 102,498 | 40,913 | 167,500 |
| Lower quartile | 14,200 | 31,869 | 62,016 | 18,519 | 74,900 |
| Upper quartile | 21,800 | 38,760 | 76,228 | 24,548 | 104,500 |
| **Average** | **18,331** | **33,965** | **69,613** | **22,310** | **90,313** |
| Standard deviation | 5,999 | 7,066 | 11,066 | 5,614 | 23,293 |

## B) Brandt's bat (*M. brandtii*): Call type B

Three recording sequences contained "double calls", which consist of two downward frequeny-modulated elements. The first pulse shows again a reversal of the frequency modulation at the end of the call, which results in a "hook shape" in the sonogram (Fig. 5.2.1.3 b). The pauses between the two call elements are 12-13 ms. Maximum values of the initial and final frequency show that the calls can sweep the frequency range from almost 100 kHz to below 20 kHz (Tab. 5.2.1.3 b). This type of call was most often heard when several animals were swarming in front of the roosts. It is possibly a variant of call type A.

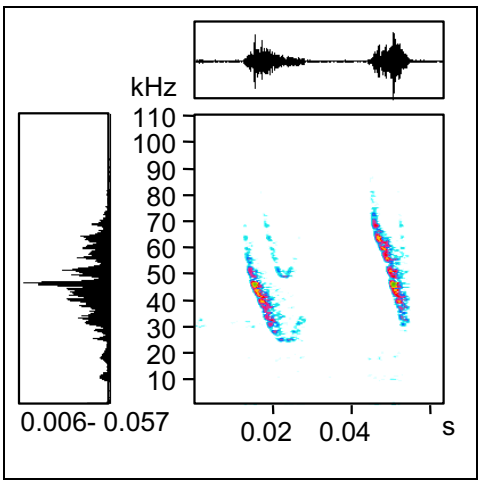


**Fig. 5.2.1.3 b:** Social call of call type B from Brandt's bat (*M. brandtii*) while several animals swarmed in front of the roost (Bat box near Dannenfels, 1 July 2000, 23:18)

**Tab. 5.2.1.3 b:** Statistical parameters of call type B from Brandt's bat (*M. brandtii*)

| | Duration [ms] | $F_{max}$ [kHz] | $F_{start}$ [kHz] | $F_{end}$ [kHz] | Duration 1st pulse [ms] | Duration 2nd pulse [ms] | $F_{max}$ 1st pulse [kHz] | $F_{max}$ 2nd pulse [kHz] | $F_{end}$ 1st pulse [kHz] | $F_{end}$ 2nd pulse [kHz] | Distance P1-P2 [ms] |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Sample size | 12 | 12 | 12 | 12 | 12 | 12 | 12 | 12 | 12 | 12 | 12 |
| **Median** | **42,400** | **46,081** | **90,439** | **23,902** | **16,650** | **11,300** | **44,789** | **55,340** | **24,117** | **27,778** | **12,350** |
| Minimum | 32,200 | 40,052 | 79,673 | 19,380 | 13,900 | 8,100 | 40,052 | 46,512 | 19,380 | 26,271 | 4,900 |
| Maximum | 45,600 | 56,848 | 98,191 | 27,132 | 20,000 | 12,500 | 47,804 | 58,570 | 26,701 | 29,716 | 19,200 |
| Lower quartile | 35,850 | 42,636 | 88,501 | 23,256 | 15,100 | 10,400 | 42,205 | 50,818 | 22,825 | 27,132 | 11,750 |
| Upper quartile | 44,100 | 46,942 | 94,961 | 24,979 | 18,300 | 11,900 | 46,081 | 57,278 | 25,409 | 29,285 | 16,700 |
| **Average** | **40,400** | **45,722** | **90,906** | **23,938** | **16,825** | **11,108** | **44,287** | **53,725** | **24,010** | **28,101** | **13,408** |
| St. deviation | 4,769 | 4,345 | 5,355 | 1,965 | 1,965 | 1,206 | 2,615 | 4,208 | 2,004 | 1,134 | 4,133 |

## C) Brandt's bat (*M. brandtii*): Call type C

Five calls of this complex and melodic sounding call type were registered in a recording sequence on the 1st of July 2000 at 22:57, while intense swarming took place in front of the roost. The call consists of three to four differently structured individual elements (Fig. 5.2.1.3 c). Its peak frequency is approximately 50 kHz, the end frequency accounts 24 kHz (Tab. 5.2.1.3 c).

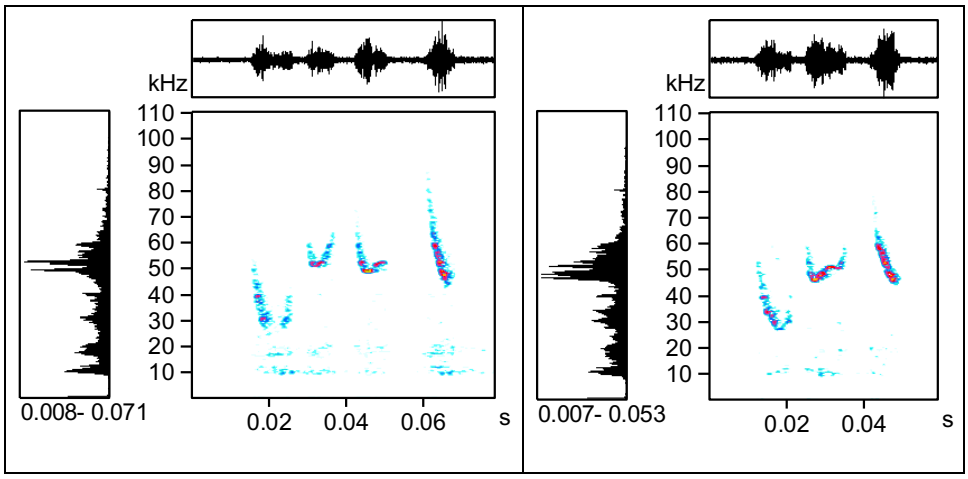


**Fig. 5.2.1.3 c:** Complex social call of call type C from Brandt's bat (*M. brandtii*) while several animals were swarming in front of the roost (Bat box near Dannenfels, 1 July 2000, 22:57)

**Tab. 5.2.1.3 c:** Statistical parameters of call type C from Brandt's bat (*M. brandtii*)

| | Duration [ms] | $F_{max}$ [kHz] | $F_{start}$ [kHz] | $F_{end}$ [kHz] |
|---|---|---|---|---|
| Sample size | 5 | 5 | 5 | 5 |
| **Median** | **37,400** | **50,388** | **82,688** | **24,117** |
| Minimum | 34,200 | 47,804 | 76,228 | 22,395 |
| Maximum | 52,800 | 52,110 | 89,578 | 25,840 |
| Lower quartile | 35,100 | 47,804 | 77,089 | 23,687 |
| Upper quartile | 38,600 | 52,110 | 88,286 | 24,548 |
| **Average** | **39,620** | **50,043** | **82,774** | **24,117** |
| Standard deviation | 7,574 | 2,162 | 6,162 | 1,256 |

## D) Brandt's bat (*M. brandtii*): Call type D

The call types D and E were registered exclusively in the period before evening emergence. Calls of the call type D last about 45 ms, start with a noisy "rasp" and pass into a wave-shaped CF part (Fig. 5.2.1.3 d). The peak frequency $F_{max}$ is about 28 kHz (Tab. 5.2.1.3 d).

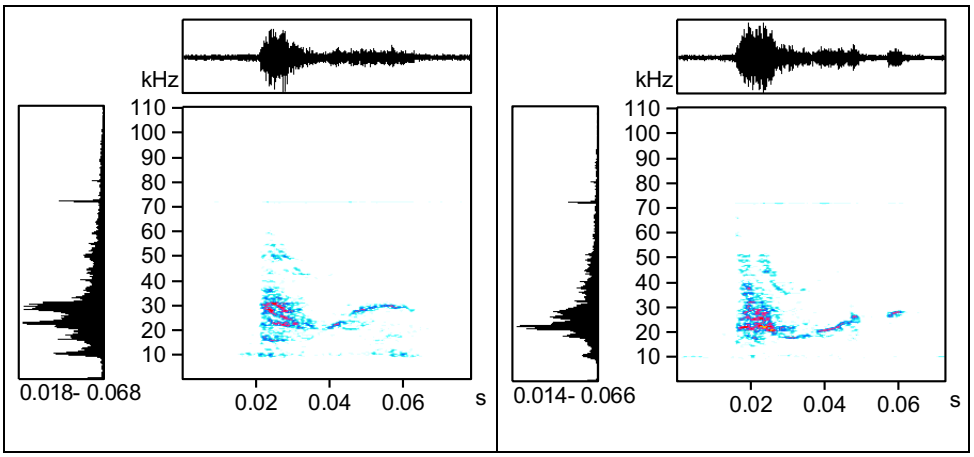


**Fig. 5.2.1.3 d:** Social call of call type D from Brandt's bat (*M. brandtii*) before the evening emergence in front of the roost (Bat box near Dannenfels, 1 July 2000, 21:46)

**Tab. 5.2.1.3 d:** Statistical parameters of call type D from Brandt's bat (*M. brandtii*)

| | Duration [ms] | $F_{max}$ [kHz] | $F_{start}$ [kHz] | $F_{end}$ [kHz] |
|---|---|---|---|---|
| Sample size | 4 | 4 | 4 | 4 |
| **Median** | **44,550** | **27,778** | **30,792** | **18,088** |
| Minimum | 39,800 | 21,964 | 29,716 | 14,212 |
| Maximum | 47,300 | 28,855 | 31,869 | 21,964 |
| Lower quartile | 41,400 | 24,763 | 29,716 | 15,504 |
| Upper quartile | 46,700 | 28,424 | 31,869 | 20,672 |
| **Average** | **44,050** | **26,594** | **30,792** | **18,088** |
| Standard deviation | 3,363 | 3,133 | 1,243 | 3,336 |

## E) Brandt's bat (*M. brandtii*): Call type E

This call type was likewise emitted during the "warm-up period" before the evening emergence. The lactating mothers and their naked and flightless juveniles were located inside the roost. The calls consist of an elongated harmonic "rasp" with an $F_{max}$ of about 28 kHz (Fig. 5.2.1.3 e). The only seven evaluated calls endure between 30 ms and more than 220 ms. Initial and final frequencies were not measurable (Tab. 5.2.1.3 e).

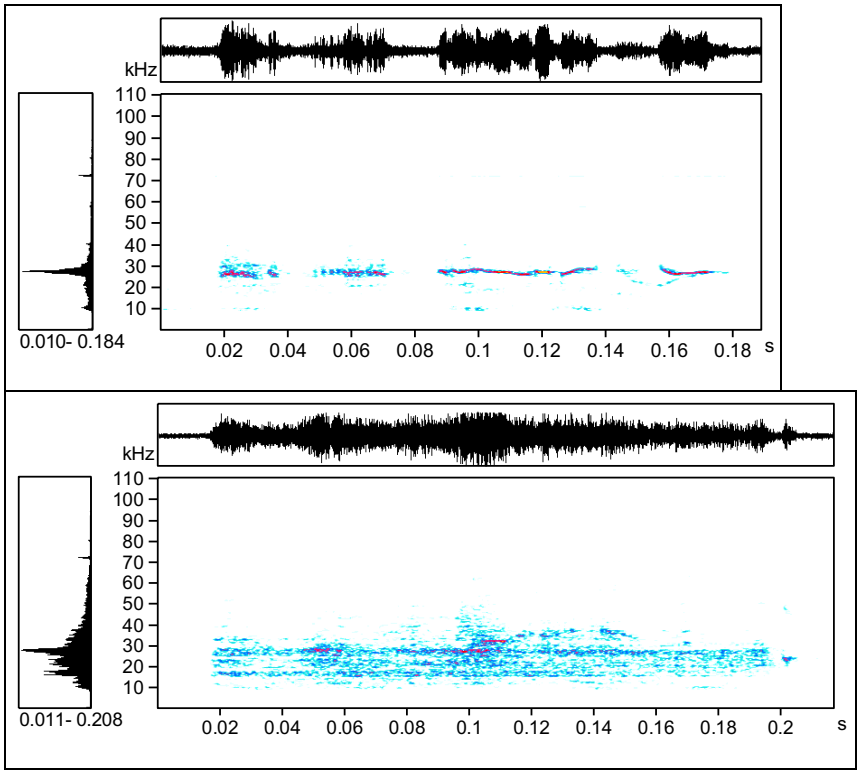


**Fig. 5.2.1.3 e:** Social call of call type E from Brandt's bat (*M. brandtii*) before the evening emergence in front of the roost (Bat box near Dannenfels, 1 July 2000, 21:31)

**Tab. 5.2.1.3 e:** Statistical parameters of call type E from Brandt's bat (*M. brandtii*)

| | Duration [ms] | $F_{max}$ [kHz] |
|---|---|---|
| Sample size | 7 | 7 |
| **Median** | **157,900** | **27,993** |
| Minimum | 30,200 | 25,840 |
| Maximum | 222,600 | 31,008 |
| Lower quartile | 67,300 | 26,271 |
| Upper quartile | 190,100 | 27,993 |
| **Average** | **136,043** | **27,747** |
| Standard deviation | 70,171 | 1,684 |

## F) Brandt's bat (*M. brandtii*): Call type F

This "trill-like" sound was recorded once during the evening swarm period about 45 minutes after the mothers started leaving the roost and four times during the morning swarm period from about an hour to 15 minutes before sunrise. In the increasing dawn twilight, at two instances while detecting these calls (5:07 am and 5:09 am), bats entering the roost could be observed. Presumably the calls were emitted by the adult bats flying in. The "trill" consists of nine to sixteen very steep and short FM bursts with pulse intervals of 4.9 - 8.7 ms (median: 6.4 ms) without a clear peak frequency (Fig. and Tab. 5.2.1.3 f).

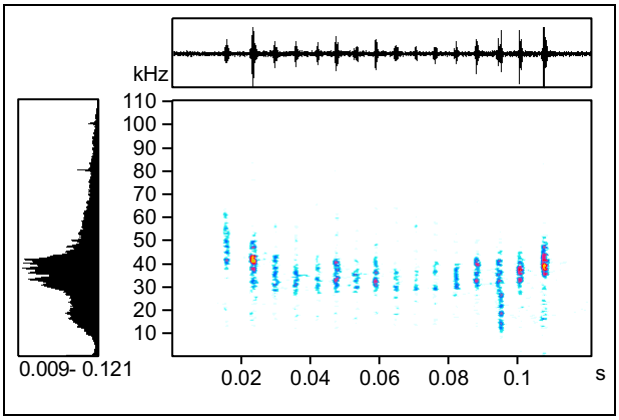


**Fig. 5.2.1.3 f:** "Trill-like" call (Call type F) from Brandt's bat (*M. brandtii*) entering the roost (Bat box near Dannenfels, 2 July 2000, 5:09, 15 minutes before sunrise)

**Tab. 5.2.1.3 f:** Statistical parameters of call type F from Brandt's bat (*M. brandtii*)

| | Länge [ms] | $F_{max}$ [kHz] | $F_{start}$ [kHz] | $F_{end}$ [kHz] | Pulse interval [ms] |
|---|---|---|---|---|---|
| Sample size | 5 | 5 | 5 | 5 | 59 |
| **Median** | **81,850** | **34,238** | **54,264** | **20,672** | **6,400** |
| Minimum | 51,100 | 18,088 | 42,636 | 9,044 | 4,900 |
| Maximum | 92,900 | 36,606 | 57,278 | 24,117 | 8,700 |
| Lower quartile | 74,300 | 27,563 | 52,110 | 13,351 | 5,800 |
| Upper quartile | 92,900 | 36,606 | 57,278 | 24,117 | 7,000 |
| **Average** | **80,500** | **41,789** | **60,092** | **31,309** | **8,056** |
| Standard deviation | 17,601 | 29,329 | 20,186 | 34,141 | 12,602 |

# 5.2.1.4 Whiskered bat (*Myotis mystacinus*, KUHL, 1817)

Social calls from Whiskered bat (*M. mystacinus*) were recorded while mist netting in a basalt mine near Mendig. These were calls from an adult bat caught in the net and a hand-held juvenile.

## A) Whiskered bat (*M. mystacinus*): Call type A

This short "trill-like" call (Fig. 5.2.1.4 a) was emitted from an adult specimen of Whiskered bat (*M. mystacinus*). The call endures between 30 ms and 55 ms and the pulse intervals of the individual elements are approximately 7.4 ms. The peak frequency is 34 - 39 kHz (median: 36 kHz). In the recorded sequence the individual trills were arranged one after another with more or less regular silent periods of approximately 65 ms (Tab. 5.2.1.4 a).

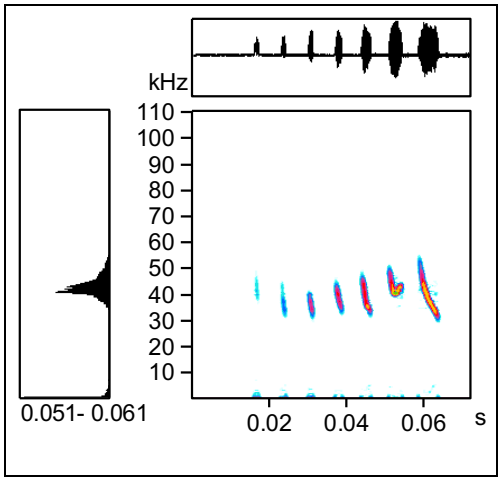


**Fig. 5.2.1.4 a:** "Trill-like" call of call type A from an adult Whiskered bat (*M. mystacinus*) after being caught in a mist net (Basalt mine near Mendig, 21 August 1998, 20:34)

**Tab. 5.2.1.4 a:** Statistical parameters of call type A from Whiskered bat (*M. mystacinus*)

| | Duration [ms] | $F_{max}$ [kHz] | $F_{start}$ [kHz] | $F_{end}$ [kHz] | Call pauses [ms] | Pulse interval [ms] |
|---|---|---|---|---|---|---|
| Sample size | 11 | 11 | 11 | 11 | 13 | 42 |
| **Median** | **40,900** | **36,176** | **55,556** | **27,132** | **65,300** | **7,400** |
| Minimum | 29,900 | 34,023 | 50,818 | 24,548 | 51,400 | 7,000 |
| Maximum | 55,400 | 39,190 | 60,724 | 27,993 | 78,100 | 8,400 |
| Lower quartile | 39,800 | 34,884 | 55,125 | 24,979 | 62,400 | 7,300 |
| Upper quartile | 47,000 | 37,037 | 57,278 | 27,563 | 68,500 | 7,500 |
| **Average** | **42,427** | **36,097** | **55,986** | **26,505** | **65,623** | **7,436** |
| Standard deviation | 6,937 | 1,539 | 2,798 | 1,353 | 6,575 | 0,298 |

## B) Whiskered bat (*M. mystacinus*): Call type B

The calls of this type were recorded from a hand-held young animal. They are similar to those of call type A but the frequency pattern of the FM pulses appears not "clear" but rather noisy in the sonogram (Fig. 5.2.1.4 b), thereby creating a "croaking" sound. The single-trills of this call type are also arranged in a series of calls and the silent periods with a median of 64.7 ms have a similar length as in call type A. The value for $F_{max}$ (median: 35.1 kHz) also matches quite well (Tab. 5.2.1.4 b).

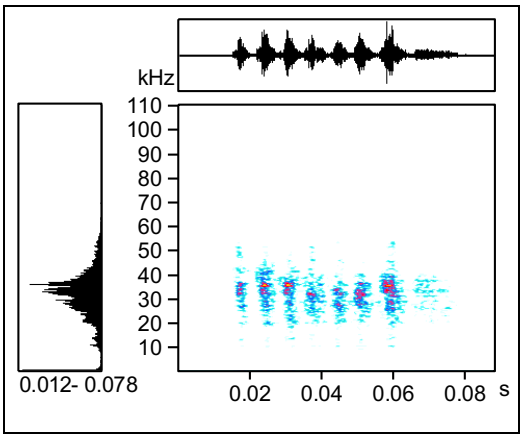


**Fig. 5.2.1.4 b:** "Trill-like" call of call type B from a hand-held juvenile Whiskered bat (*M. mystacinus*) after being caught in a mist net (Basalt mine near Mendig, 21 August 1998, 22:45)

**Tab. 5.2.1.4 b:** Statistical parameters of call type B from Whiskered bat (*M. mystacinus*)

| | Duration [ms] | $F_{max}$ [kHz] | Call pauses [ms] |
|---|---|---|---|
| Sample size | 20 | 20 | 31 |
| **Median** | **56,450** | **35,099** | **64,700** |
| Minimum | 36,900 | 31,869 | 49,300 |
| Maximum | 120,500 | 38,329 | 79,500 |
| Lower quartile | 44,650 | 33,807 | 59,800 |
| Upper quartile | 72,400 | 37,252 | 67,900 |
| **Average** | **62,145** | **35,422** | **64,384** |
| Standard deviation | 22,556 | 1,946 | 7,621 |

## 5.2.1.5 Natterer's bat (*Myotis nattereri*, KUHL, 1817)

In the course of this work, the social calls of Natterer's bat were recorded around a batbox with a maternity colony near Otterberg on the evening of the 7th of July 1999. In the afternoon of the same day, seven adults and seven juveniles of *M. nattereri*, probably not yet or only recently flying, were found monitoring the bat boxes. The recorded social calls from this evening (31 sequences) and two further recordings from a batbox monitoring on the 4th of July 1998 were classified into five call types.

### A) Natterer's bat (*M. nattereri*): Call type A

This call type was presumably emitted by juveniles, partly out of the roost before evening emergence but mostly during swarming activity in front of the batbox. Observations on the evening of the 7th of July 1999 suggest that none or only single juveniles left the roost at night.

Call type A includes "V-shaped" calls with an initially steeply decreasing FM part. From the lowest frequency, the call then shows a mirror-like frequency response, this time with steeply increasing frequency modulation. Often, this V-structure follows a steep FM burst with a frequency response similar to the echolocating calls (Fig. 5.2.1.5 a1). The calls have a bandwidth of up to 84 kHz (minimum: 13.8 kHz, maximum: 97.8 kHz) and partially reach the audible frequency range. The median of the peak frequency is about 38 kHz (Tab. 5.2.1.5 a1).

A high frequency variant of this call type A (Fig. 5.2.1.5 a2) was recorded in 17 cases. The median of the call maximum is here 44.4 kHz; the final frequency of the V element is between 34.9 kHz and 54.7 kHz (Tab. 5.2.1.5 a2). The calls were made in the same situations as the lower-frequency "V-calls" and were individually integrated into the call sequences.

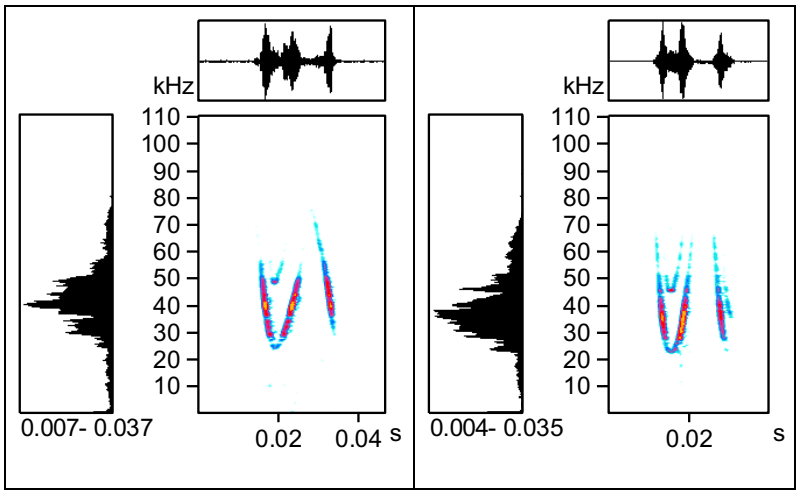


**Fig. 5.2.1.5 a1:** "V-shaped" social call (call type A) at a maternity roost from Natterer's bat (*M. nattereri*) during swarming activity (Batbox near Otterberg, 7 July 1999, 22:58 and 23:26)

**Tab. 5.2.1.5 a1:** Statistical parameters of call type A from Natterer's bat (*M. nattereri*)

| | Duration V [ms] | $F_{max}$ [kHz] | $F_{start}$ [kHz] | $F_{end}$ [kHz] |
|---|---|---|---|---|
| Sample size | 38 | 37 | 37 | 37 |
| **Median** | **11,450** | **37,898** | **78,381** | **23,256** |
| Minimum | 7,800 | 26,701 | 63,308 | 13,781 |
| Maximum | 15,100 | 43,928 | 97,761 | 33,161 |
| Lower quartile | 9,900 | 33,161 | 71,060 | 18,519 |
| Upper quartile | 13,400 | 39,621 | 85,702 | 27,993 |
| **Average** | **16,221** | **38,083** | **79,671** | **25,679** |
| Standard deviation | 20,951 | 11,648 | 9,514 | 14,117 |

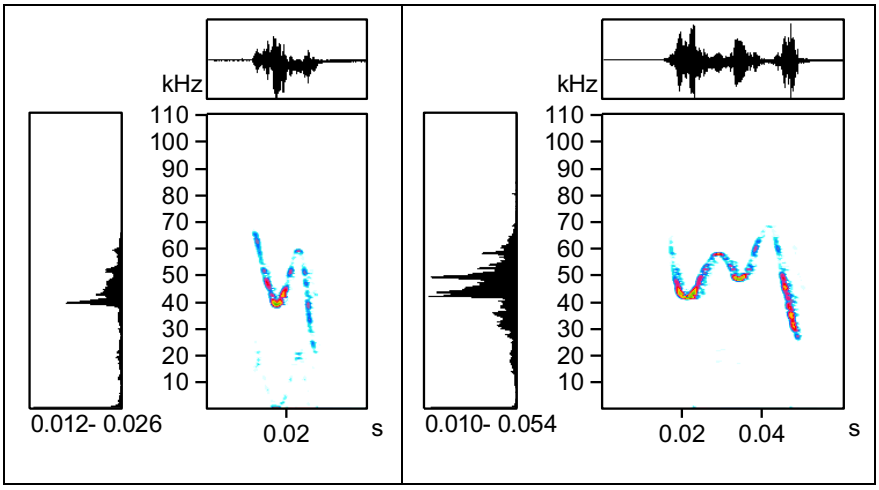


**Fig. 5.2.1.5 a2:** High frequency "V-shaped" social call from Natterer's bat (*M. nattereri*) at a maternity roost (Batbox near Otterberg, 7 July 1999, 21:43 and 22:35)

**Tab. 5.2.1.5 a2:** Statistiscal parameters of the high-frequency variant of call type A from Natterer's bat (*M. nattereri*)

| | Duration V [ms] | $F_{max}$ [kHz] | $F_{start}$ [kHz] | $F_{end}$ V [kHz] |
|---|---|---|---|---|
| Sample size | 17 | 16 | 16 | 16 |
| **Median** | **11,900** | **44,358** | **76,012** | **41,774** |
| Minimum | 6,700 | 36,606 | 67,614 | 34,884 |
| Maximum | 18,000 | 56,417 | 92,593 | 54,694 |
| Lower quartile | 7,500 | 40,698 | 71,060 | 37,468 |
| Upper quartile | 12,800 | 48,234 | 82,257 | 45,220 |
| **Average** | **21,294** | **47,791** | **77,956** | **45,252** |
| Standard deviation | 30,721 | 15,000 | 9,131 | 15,439 |

## B) Natterer's bat (*M. nattereri*): Call type B

The social calls of call type B differ from the previous one by a CF part inserted in the middle of the call. As a result, the calls are extended and the sound energy is focused to lower frequency ranges (median of $F_{max}$: 21.5 kHz). The minimum frequency of the calls is often in the human audible range (down to 14.2 kHz). Frequently, two "U-shaped" elements are emitted one after anaother as a "double call", sometimes but rarely even "triple calls" occur (Fig. 5.2.1.5 b). The pulse intervals of the double calls (measured between the vertexes of the two "U-elements") are relatively regular (median: 18.6 ms). Sometimes, series of double calls were registered with silent periods from 57 to 95 ms (median: 72.6 ms) (Tab. 5.2.1.5 b).

The first calls of this type were recorded after the first individual had left the roost. Later on, call type B was registered during intense swarming activity.

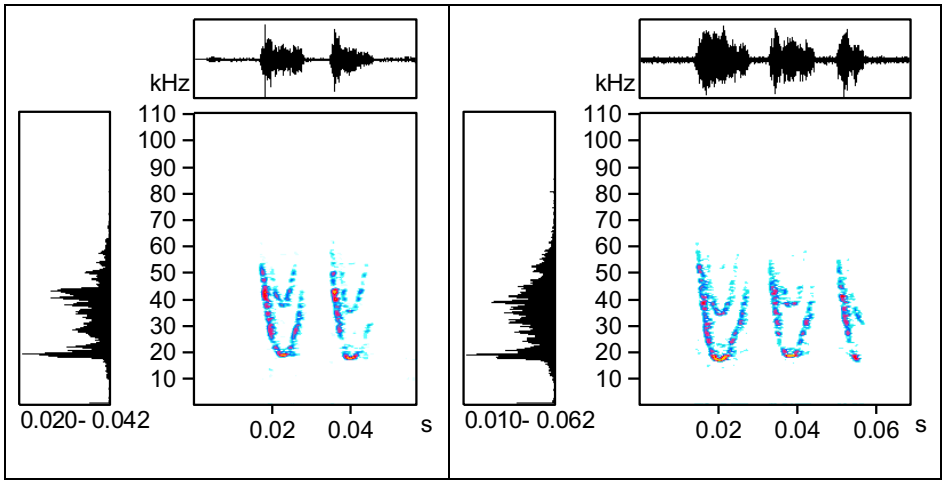


**Fig. 5.2.1.5 b:** "U-shaped" social call of type B from a maternity roost of Natterer's bat (*M. nattereri*) during intense swarming activity; Left: "Double call", Right: rarer "triple call" (Nestbox near Otterberg, 7 July 1999, 23:42)

**Tab. 5.2.1.5 b:** Statistical parameters of call type B from Natterer's bat (*M. nattereri*) (D = Double call)

| | Duration U [ms] | $F_{max}$ [kHz] | $F_{start}$ [kHz] | $F_{end}$ [kHz] | Duration D [ms] | Pulse interval D [ms] | Call pauses D [ms] |
|---|---|---|---|---|---|---|---|
| Sample size | 65 | 65 | 65 | 65 | 41 | 41 | 21 |
| **Median** | **12,800** | **21,533** | **72,782** | **19,811** | **25,800** | **18,600** | **72,600** |
| Minimum | 8,400 | 15,504 | 59,432 | 14,212 | 22,100 | 16,300 | 56,600 |
| Maximum | 17,700 | 38,760 | 97,330 | 36,606 | 33,100 | 22,900 | 95,200 |
| Lower quartile | 11,900 | 19,380 | 68,476 | 17,227 | 24,400 | 18,000 | 65,600 |
| Upper quartile | 14,500 | 24,117 | 80,965 | 22,395 | 27,300 | 19,400 | 73,700 |
| **Average** | **13,182** | **22,388** | **75,154** | **20,334** | **25,902** | **19,044** | **71,338** |
| Standard deviation | 1,844 | 4,609 | 10,156 | 4,411 | 2,274 | 1,597 | 9,335 |

## C) Natterer's bat (*M. nattereri*): Call type C

This "trill-like" call was recorded on the afternoon of the 4th of July 1998 while monitoring bat-boxes and also on the evening of the 7th of July 1999 from a maternity colony located in another batbox. In the evening, that call type was registered before and while the bats emerged, as well as during later swarming periods. It consists of a series of steep FM pulses with an $F_{max}$ at approximately 32.5 kHz. The pulse intervals have a relatively constant time duration of approximately 9.3 ms and the total length of the call varies greatly depending on the number of FM pulses (Fig. und Tab. 5.2.1.5 c).

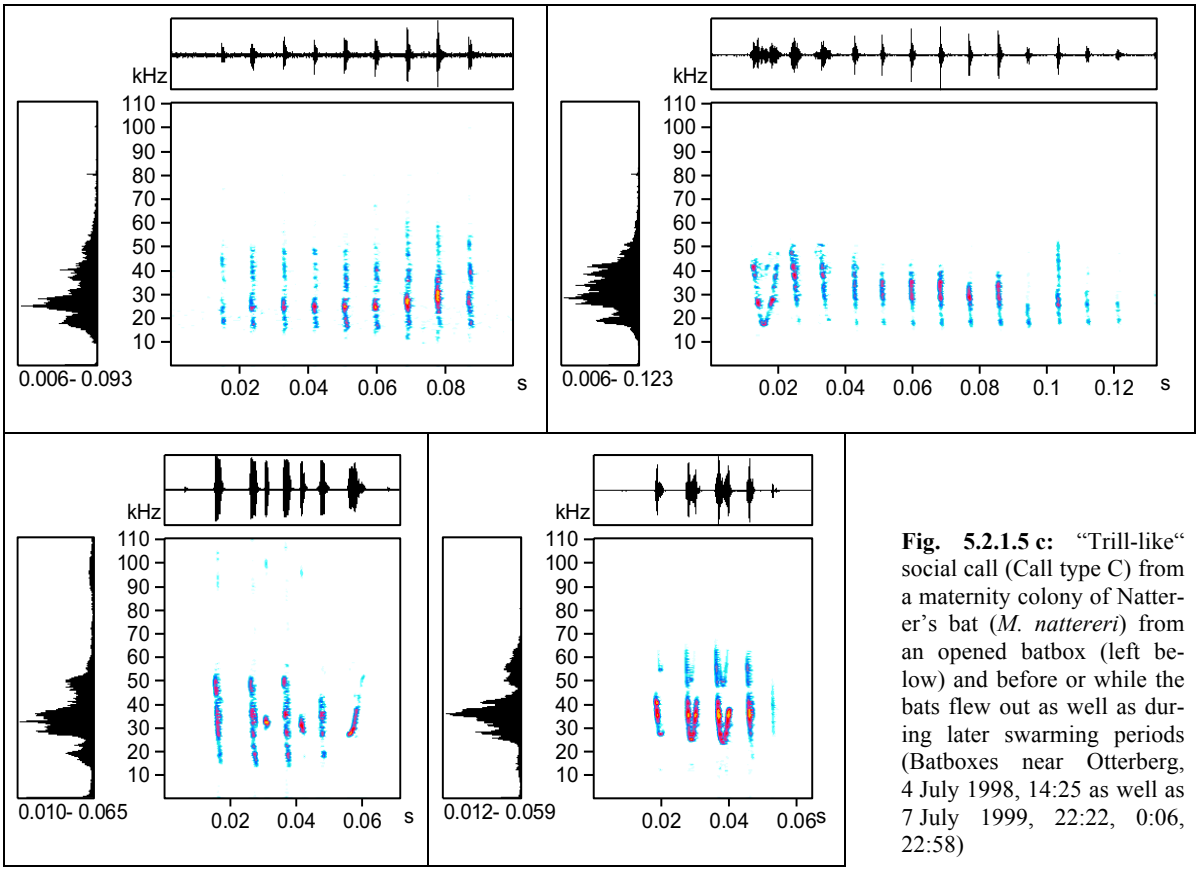


**Fig. 5.2.1.5 c:** "Trill-like" social call (Call type C) from a maternity colony of Natterer's bat (*M. nattereri*) from an opened batbox (left below) and before or while the bats flew out as well as during later swarming periods (Batboxes near Otterberg, 4 July 1998, 14:25 as well as 7 July 1999, 22:22, 0:06, 22:58)

**Tab. 5.2.1.5 c:** Statistical parameters of call type C from Natterer's bat (*M. nattereri*)

| | Duration [ms] | $F_{max}$ [kHz] | $F_{start}$ [kHz] | $F_{end}$ [kHz] | Pulse interval [ms] |
|---|---|---|---|---|---|
| Sample size | 26 | 26 | 26 | 26 | 134 |
| **Median** | **44,400** | **32,515** | **55,340** | **15,719** | **9,300** |
| Minimum | 21,800 | 24,979 | 38,329 | 11,197 | 7,000 |
| Maximum | 111,200 | 43,497 | 91,301 | 26,271 | 14,200 |
| Lower quartile | 36,000 | 29,285 | 51,680 | 14,212 | 8,700 |
| Upper quartile | 65,600 | 35,745 | 65,892 | 20,672 | 10,200 |
| **Average** | **52,323** | **33,128** | **58,686** | **16,928** | **9,607** |
| Standard deviation | 22,368 | 4,681 | 11,743 | 4,123 | 1,223 |

## D) Natterer's bat (*M. nattereri*): Call type D

This type of call was also recorded on the evening of the 7th of July 1999 before and while the bats left their roost in a batbox, as well as during later swarming periods. These are generally sounds with a "raspy" beginning part, and a more or less constant frequency final part with "cheeping" sound quality (Fig. 5.2.1.5 d). In the 27 measured calls, the $F_{max}$ ranges between 25.8 kHz and 41.8 kHz (median: approx. 33 kHz), the total length of the calls varies greatly (Tab. 5.2.1.5 d).

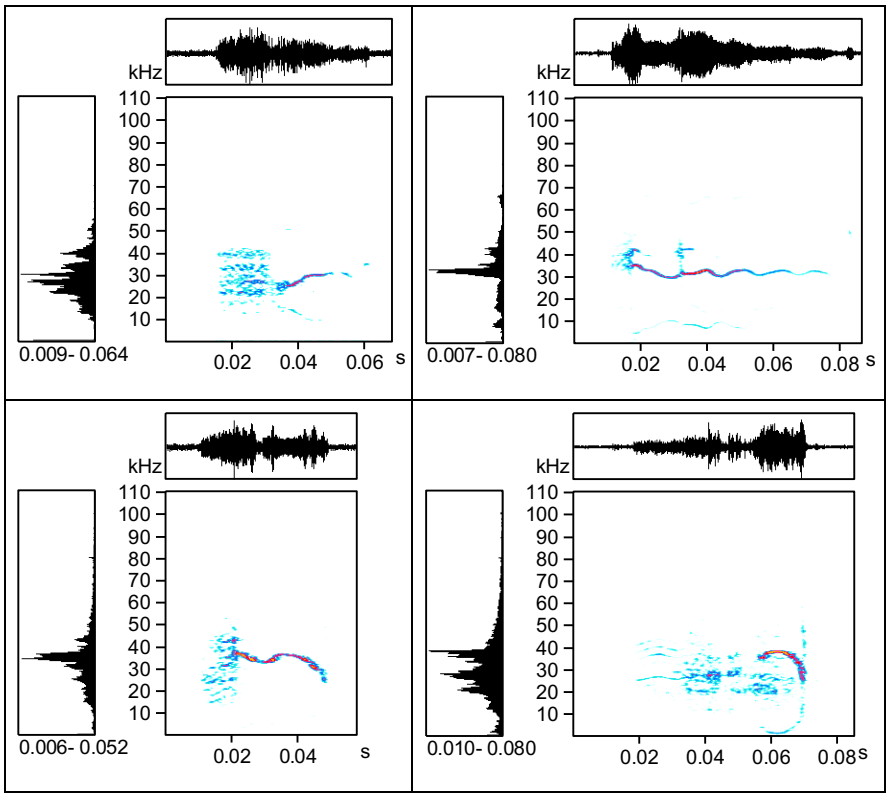


**Fig. 5.2.1.5 d:** Social call of call type D from a maternity colony of Natterer's bat (*M. nattereri*) before or while the bats left their roost in a batbox, as well as during later swarming periods (Batbox near Otterberg, 7 July 1999, 21:51, 22:13, 22:23 and 22:19)

**Tab. 5.2.1.5 d:** Statistical parameters of call type D from Natterer's bat (*M. nattereri*)

| | Duration [ms] | $F_{max}$ [kHz] |
|---|---|---|
| Sample size | 27 | 27 |
| **Median** | **56,600** | **32,731** |
| Minimum | 34,800 | 25,840 |
| Maximum | 94,300 | 41,774 |
| Lower quartile | 45,300 | 30,147 |
| Upper quartile | 69,700 | 38,329 |
| **Average** | **58,715** | **33,703** |
| Standard deviation | 16,610 | 4,630 |

## E) Natterer's bat (*M. nattereri*): Call type E

The long-lasting "raspy" calls of this call type were also recorded during the monitoring of bat-boxes on July 4th 1998 and on the evening of July 7th 1999 from a maternity colony being located in another batbox. The multi-harmonic "croaking" noise is usually terminated by an initially constant-frequency and then abruptly declining part (Fig. 5.2.1.5 e). The total length of the call is very fluctuant, the peak frequency lies between 24.5 kHz and 40.5 kHz. Initial and final frequencies are not measurable (Tab. 5.2.1.5 e).

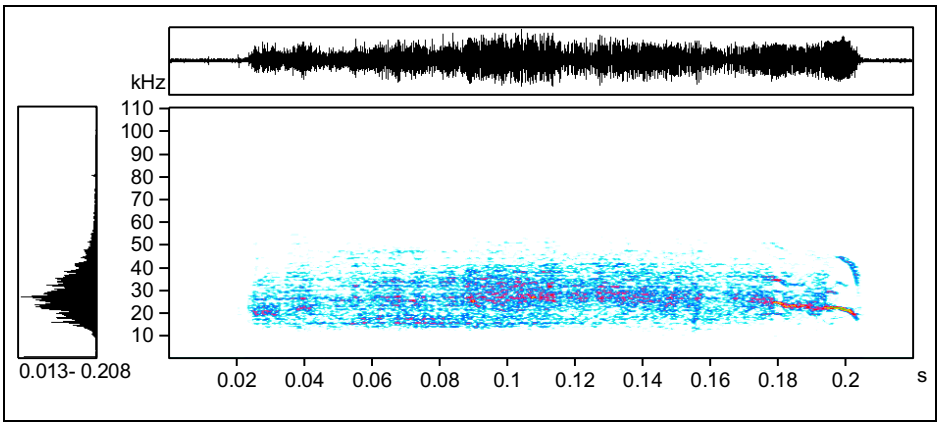


**Fig. 5.2.1.5 e:** Social calls of call type E from a maternity colony of Natterer's bat (*M. nattereri*) (Batbox near Otterberg, 4 July 1998, 14:32)

**Tab. 5.2.1.5 e:** Statistical parameters of call type E from Natterer's bat (*M. nattereri*)

| | Duration [ms] | $F_{max}$ [kHz] |
|---|---|---|
| Sample size | 22 | 22 |
| **Median** | **173,000** | **30,792** |
| Minimum | 69,100 | 24,548 |
| Maximum | 261,800 | 40,482 |
| Lower quartile | 101,000 | 26,701 |
| Upper quartile | 213,000 | 34,023 |
| **Average** | **157,536** | **30,675** |
| Standard deviation | 56,076 | 4,489 |

## 5.2.1.6 Bechstein's bat (*Myotis bechsteinii*, KUHL, 1817)

The social calls from Bechstein's bat were mainly recorded on the 20th/21st of July 2000 at a batbox near Göllheim in the northern foothills of Palatinate Forest. Some recorded sequences from the evening of the 7th and the morning of the 8th of August 1999 originate from a batbox monitoring area near Harthausen. Six call types can be distinguished.

### A) Bechstein's bat (*M. bechsteinii*): Call type A

Social calls of call type A are among the most conspicuous calls of Bechstein's bat and were observed during intense morning or nightly swarming periods. The signal structure and the temporal changes of volume within a recording sequence indicate that the calls were emitted in flight from the bats swarming in front of the roost (compared call type B: calls from inside the roost). These very loud and extremely broadband-frequency calls show an initially steeply falling and then flattening frequency-modulation (Fig. 5.2.1.6 a). The frequency range of the calls covers more than 88 kHz (the highest measured frequency is 104.2 kHz, the lowest is 15.9 kHz). The median of the peak frequency is 35.7 kHz, the median of the call duration is 18.6 ms (Tab. 5.2.1.6 a).

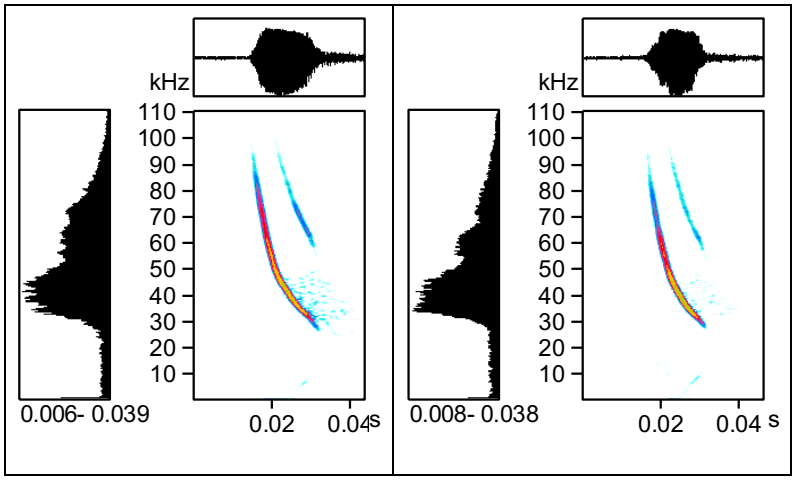


**Fig. 5.2.1.6 a:** Social calls (Call type A) from Bechstein's bat (*M. bechsteinii*) while swarming in front of the roost (Batbox near Göllheim, 20 July 2000, 23:53)

**Tab. 5.2.1.6 a:** Statistical parameters of call type A from Bechstein's bat (*M. bechsteinii*)

| | Duration [ms] | $F_{max}$ [kHz] | $F_{start}$ [kHz] | $F_{end}$ [kHz] |
|---|---|---|---|---|
| Sample size | 73 | 73 | 73 | 73 |
| **Median** | **18,600** | **35,745** | **82,257** | **21,964** |
| Minimum | 9,900 | 29,716 | 62,877 | 15,935 |
| Maximum | 35,100 | 44,358 | 104,221 | 28,855 |
| Lower quartile | 16,800 | 34,023 | 75,797 | 20,672 |
| Upper quartile | 22,300 | 38,760 | 92,593 | 24,548 |
| **Average** | **19,215** | **36,005** | **83,950** | **22,569** |
| Standard deviation | 4,543 | 3,257 | 10,587 | 2,610 |

## B) Bechstein's bat (*M. bechsteinii*): Call type B

Social calls of this call type were emitted by Bechstein's bats from inside maternity roosts. It was only after the first animal's emergence that the call was registered. The most intense calling activity occurred during nightly swarming periods. A total of 531 single calls of this type were analysed. Similar to call type A, it is a downward-modulated FM pulse, but its frequency drops relatively slowly causing a "prolongation" of the call (Fig. 5.2.1.6 b). Similar to the calls emitted in flight, the median of the peak frequency $F_{max}$ is 34.9 kHz, but the calls are about 10 ms longer (median of call duration: 29 ms). The frequency bandwidth of the calls is almost 94 kHz (108.5 kHz → 14.6 kHz). They are often arranged one after another in call series, with silent periods between the calls of about 118 ms (Tab. 5.2.1.6 b).

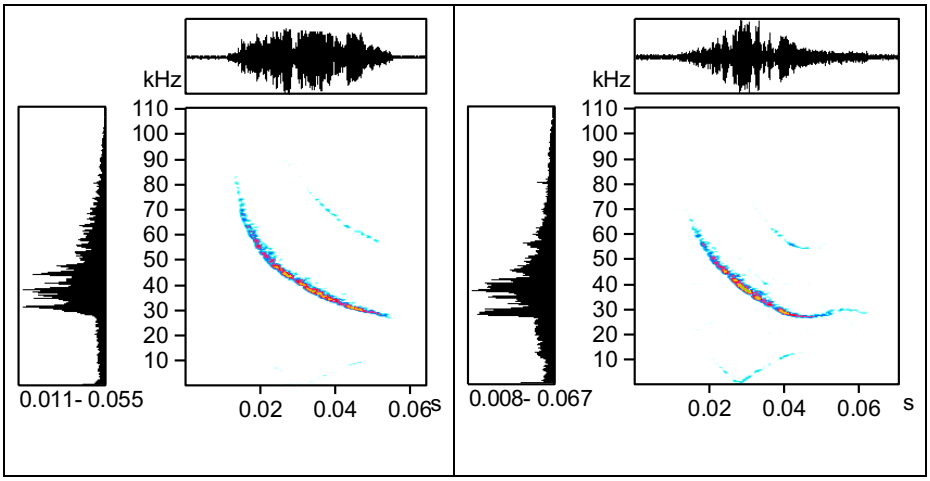


**Fig. 5.2.1.6 b:** Social calls emitted from inside the roost (Call type B) from Bechtein's bat (*M. bechsteinii*) (Batbox near Göllheim, 20 July 2000, 23:01 and 1:01)

**Tab. 5.2.1.6 b:** Statistical parameters of call type B from Bechstein's bat (*M. bechsteinii*)

| | Duration [ms] | $F_{max}$ [kHz] | $F_{start}$ [kHz] | $F_{end}$ [kHz] | Call pauses [ms] |
|---|---|---|---|---|---|
| Sample size | 531 | 527 | 531 | 531 | 93 |
| **Median** | **29,000** | **34,884** | **83,549** | **21,533** | **118,400** |
| Minimum | 15,700 | 23,687 | 54,694 | 14,643 | 76,300 |
| Maximum | 54,600 | 46,081 | 108,527 | 34,023 | 161,400 |
| Lower quartile | 24,400 | 33,161 | 77,950 | 19,380 | 105,900 |
| Upper quartile | 34,800 | 37,468 | 93,023 | 24,117 | 131,800 |
| **Average** | **30,008** | **34,971** | **84,761** | **22,139** | **118,304** |
| Standard deviation | 7,584 | 3,913 | 9,879 | 3,578 | 19,803 |

## C) Bechstein's bat (*M. bechsteinii*): Call type C

On rare occasions the high-frequency calls of this call type were observed. They start as steeply descending FM pulses, reaching their lowest frequency approximately in the middle of the call and ending with a steeply ascending frequency modulation (Fig. 5.2.1.6. c, left). The peak frequency (median: 46.1 kHz) is close to the lowest frequency of the call (median: 44.6 kHz) and the maximum frequency reaches almost 100 kHz (Tab. 5.2.1.6 c). Rarely, an elongated broad-frequency FM pulse of call type B (Fig. 5.2.1.6. c, right) directly follows this call. The statistical parameters of this rare call type C and the even less frequently emitted "double calls" are listed here only for the sake of completeness (Tab. 5.2.1.6 c).

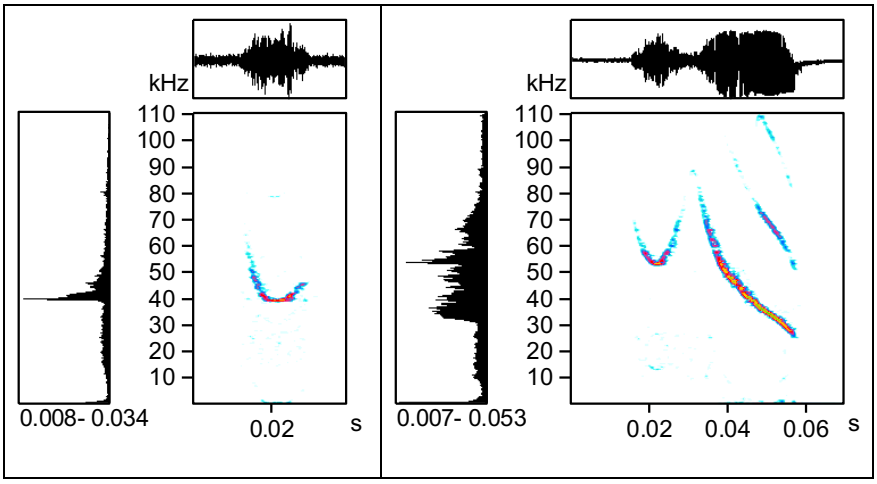


**Fig. 5.2.1.6 c:** Social calls emitted from inside of the roost (Call type C) from Bechtein's bat (*M. bechsteinii*); Left: single high-frequency call; Right: "Double call" (Batbox near Göllheim, 20 July 2000, 23:02, 21:32)

**Tab. 5.2.1.6 c:** Statistical parameters of call type C from Bechstein's bat (*M. bechsteinii*)

| | **Single call C** | | | | **Double call C-B** | | | |
|---|---|---|---|---|---|---|---|---|
| | Duration [ms] | $F_{max}$ [kHz] | $F_{start}$ [kHz] | $F_{end}$ [kHz] | Duration [ms] | $F_{max}$ [kHz] | $F_{start}$ [kHz] | $F_{end}$ C [kHz] |
| Sample size | 4 | 4 | 4 | 4 | 2 | 2 | 2 | 2 |
| **Median** | **16,250** | **46,081** | **82,257** | **44,574** | **22,650** | **48,880** | **103,575** | **47,158** |
| Minimum | 15,400 | 39,621 | 73,213 | 37,898 | 21,800 | 46,512 | 98,622 | 44,789 |
| Maximum | 18,600 | 53,402 | 98,622 | 51,680 | 23,500 | 51,249 | 108,527 | 49,526 |
| Lower quartile | 15,700 | 39,836 | 74,290 | 38,329 | - | - | - | - |
| Upper quartile | 17,550 | 52,756 | 93,885 | 51,034 | - | - | - | - |
| **Average** | **16,625** | **46,296** | **84,087** | **44,681** | **22,650** | **48,880** | **103,575** | **47,158** |
| Standard deviation | 1,391 | 7,480 | 11,989 | 7,362 | 1,202 | 3,350 | 7,004 | 3,350 |

## D) Bechstein's bat (*M. bechsteinii*): Call type D

28 elongated calls from this call type D were evaluated. These are more or less constant-frequency sounds with a downward frequency-modulated end section. Frequently, several harmonics and sub-harmonics are visible in the sonogram (Fig. 5.2.1.6 d). The time-expanded calls have a "cheeping" sound quality and are presumably emitted by juveniles before or during the evening emergence period. The call duration is 20 - 130 ms, the peak frequency lays around 29 kHz (Tab. 5.2.1.6 d).

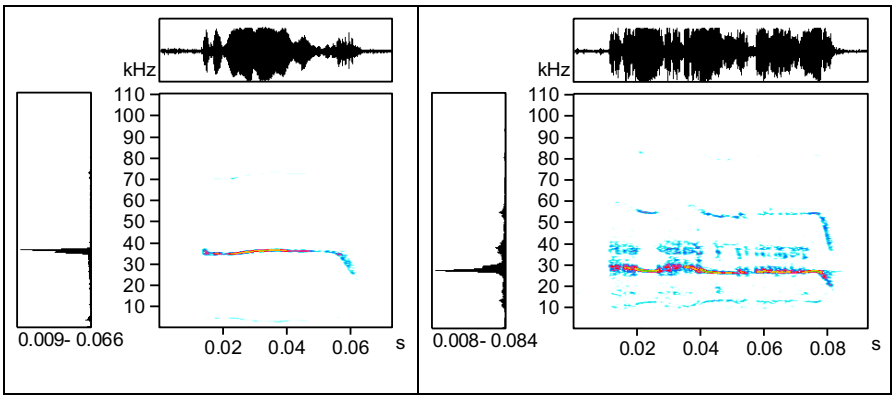


**Fig. 5.2.1.6 d:** "Cheeping" social calls emitted from a maternity roost (Call type D) from Bechtein's bat (*M. bechsteinii*) (Batbox near Göllheim, 20 July 2000, 22:23 and 21:36)

**Tab. 5.2.1.6 d:** Statistical parameters of call type D from Beschtein's bat (*M. bechsteinii*)

| | Duration [ms] | $F_{max}$ [kHz] |
|---|---|---|
| Sample size | 28 | 28 |
| **Median** | **41,650** | **28,639** |
| Minimum | 20,600 | 23,256 |
| Maximum | 130,000 | 36,606 |
| Lower quartile | 32,950 | 27,993 |
| Upper quartile | 48,900 | 32,300 |
| **Average** | **48,146** | **30,193** |
| Standard deviation | 25,908 | 3,418 |

## E) Bechstein's bat (*M. bechsteinii*): Call type E

The "raspy" calls of this call type are audible to humans. They were emitted immediately before and during the emergence as well as when the first bats returned to the roost approximately 2 ¼ hours after they had flown out. These are noisy sounds, which are characterised by harmonic noise bands in the sonogram. At the end of the call - similar to call type D – usually a downward frequency modulated pulse occurs (Fig. 5.2.1.6 e). The call duration is up to more than 300 ms and the median of the peak frequency is 20.2 kHz (Tab. 5.2.1.6 e).

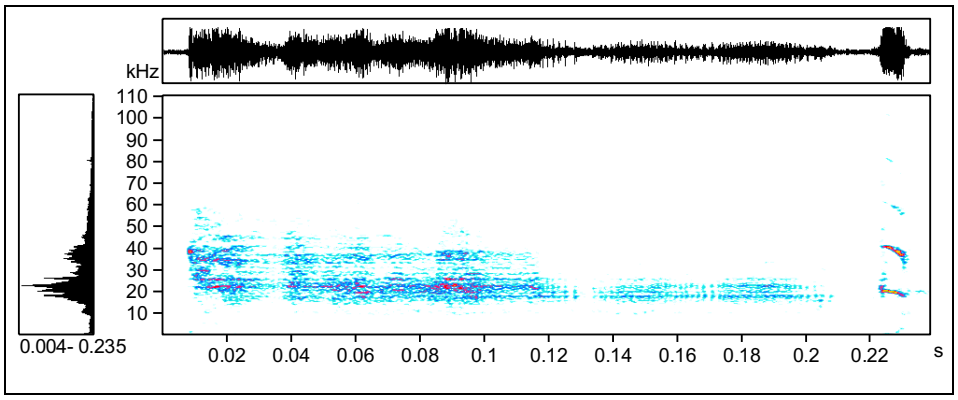


**Fig. 5.2.1.6 e:** "Raspy" social calls emitted from a maternity roost (Call type E) from Bechstein's bat (*M. bechsteinii*) (Batbox near Göllheim, 20 July 2000, 21:35)

**Tab. 5.2.1.6 e:** Statistical parameters of call type E from Bechstein's bat (*M. bechsteinii*)

| | Duration [ms] | $F_{max}$ [kHz] |
|---|---|---|
| Sample size | 16 | 16 |
| **Median** | **67,200** | **20,241** |
| Minimum | 28,700 | 16,365 |
| Maximum | 305,900 | 23,256 |
| Lower quartile | 38,300 | 17,442 |
| Upper quartile | 114,600 | 21,749 |
| **Average** | **96,463** | **19,811** |
| Standard deviation | 79,409 | 2,317 |

## F) Bechstein's bat (*M. bechsteinii*): Call type F

The "trill-like" calls of call type F were only recorded before and during the approximately 40 minute period of emergence. On the 20th of July, 37 Bechstein's bats were observed flying out in the evening before the first returnees began to swarm in front of the roost. In its basic form, the call consists of a series of steeply downward frequency-modulated single pulses where up to 21 such FM elements are lined up. Several variations of the individual pulses occur (Fig. 5.2.1.6 f). The pulse intervals are in median 8.7 ms and the peak frequency is about 36 kHz (Tab. 5.2.1.6 f).

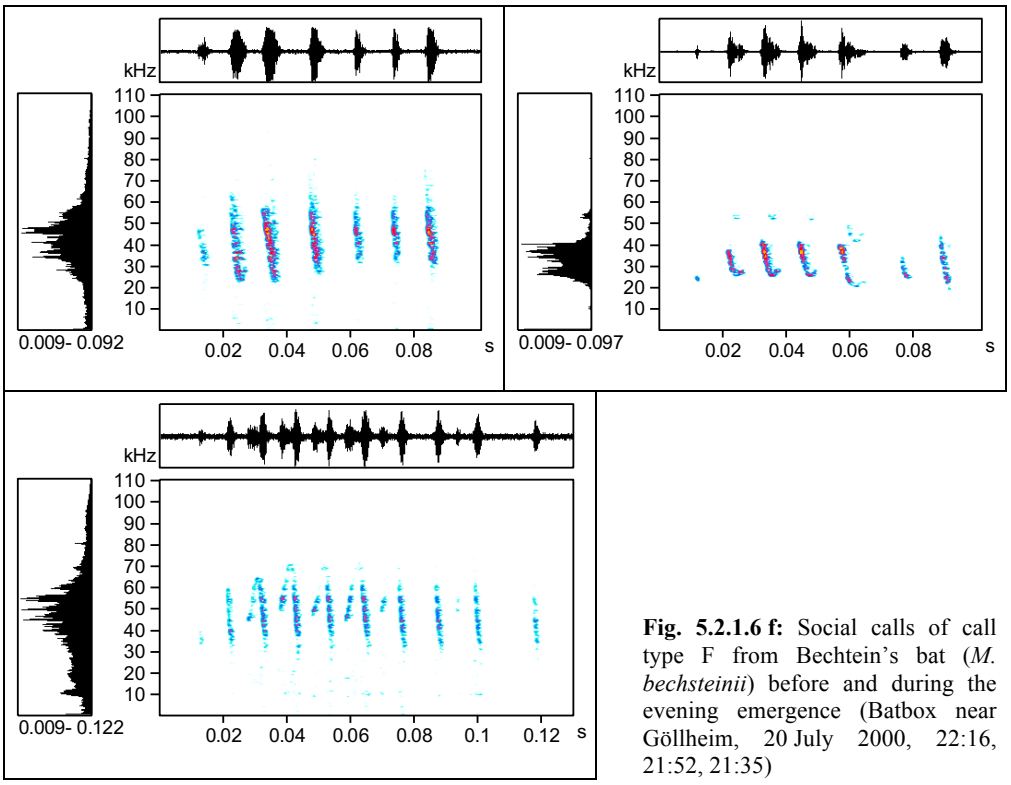


**Fig. 5.2.1.6 f:** Social calls of call type F from Bechtein's bat (*M. bechsteinii*) before and during the evening emergence (Batbox near Göllheim, 20 July 2000, 22:16, 21:52, 21:35)

**Tab. 5.2.1.6 f:** Statistical parameters of call type F from Bechtein's bat (*M. bechsteinii*)

| | Duration [ms] | $F_{max}$ [kHz] | $F_{start}$ [kHz] | $F_{end}$ [kHz] | Pulse interval [ms] |
|---|---|---|---|---|---|
| Sample size | 33 | 33 | 33 | 33 | 285 |
| **Median** | **72,600** | **36,176** | **62,877** | **21,964** | **8,700** |
| Minimum | 24,100 | 31,439 | 49,096 | 12,489 | 5,500 |
| Maximum | 180,800 | 49,096 | 76,658 | 28,855 | 20,300 |
| Lower quartile | 54,000 | 34,453 | 58,570 | 19,380 | 7,000 |
| Upper quartile | 88,200 | 39,621 | 69,768 | 24,979 | 10,400 |
| **Average** | **80,085** | **37,246** | **63,660** | **21,664** | **8,984** |
| Standard deviation | 38,434 | 4,258 | 7,223 | 4,692 | 2,153 |

## 5.2.1.7 Greater mouse-eared bat (*Myotis myotis*, BORKHAUSEN, 1797)

Social calls of the Greater mouse-eared bat were recorded on the 25th of July 2000 inside the attic of the Agricultural Research Center at Neumühle. At that time, about 50 individuals, predominantly young bats, were located inside the roost. Further recordings were made from single males at mating roosts in woodcrete boxes (type SCHWEGLER 2FN) near Kaiserslautern-Hohenecken. There, detector recordings took place at eight occasions from the end of July until the end of October 1999. In addition, the calls of an animal captured in a mist net were recorded in a basalt mine near Mendig. A total of six different call types can be described.

### A) Greater mouse-eared bat (*M. myotis*): Call type A

Many of these highly variable calls, originating from the attic at Neumühle, were classified as call type A (see also Chapter 5.2.3.1). Figure 5.2.1.7 a shows an example of four call-subtypes, which have been recorded at the same time (n = 13 - 29). The characteristic values of the measured call parameters are quite inhomogeneous among themselves. The peak frequency of 237 individual calls analysed varies between 23 kHz and 43 kHz (median: 25 kHz), the minimum frequency between 18 kHz and 31 kHz (median: 19.8 kHz). Partially, call series were observed with median silent periods between the calls of about 88 ms (Tab. 5.2.1.7 a).

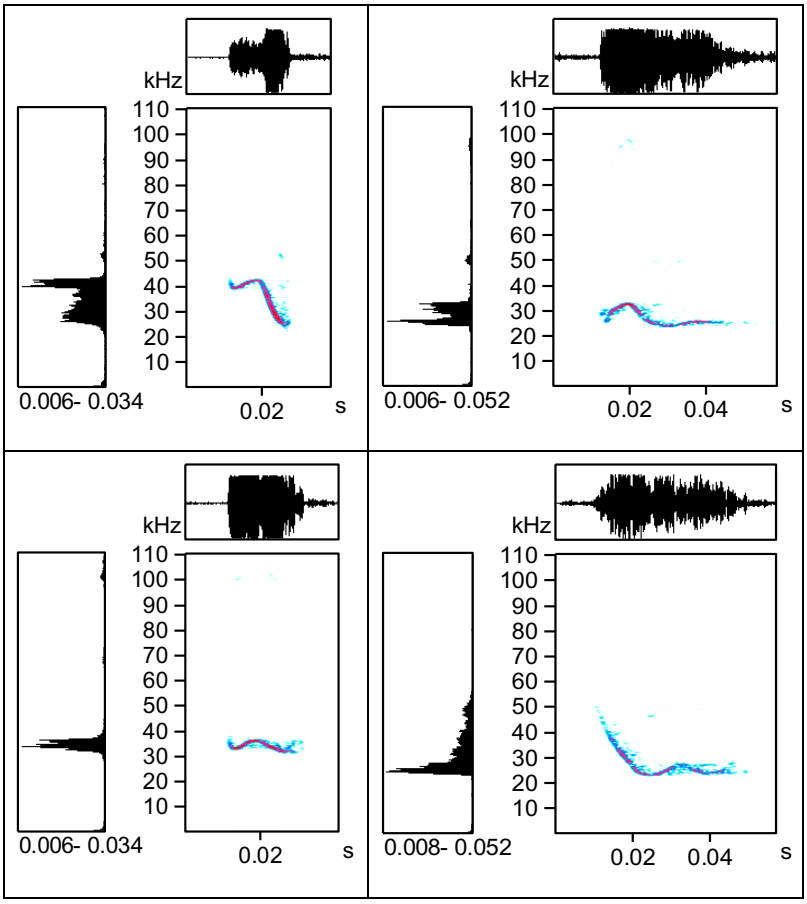


**Fig. 5.2.1.7 a:** Social calls of call type A from Greater mouse-eared bat (*M. myotis*) inside an attic before and during the evening emergence (Neumühle, 25 July 2000)

**Tab. 5.2.1.7 a:** Statistical parameters of call type A from Greater mouse-eared bat (*M. myotis*)

| | Duration [ms] | $F_{max}$ [kHz] | $F_{start}$ [kHz] | $F_{end}$ [kHz] | Call pauses [ms] |
|---|---|---|---|---|---|
| Sample size | 237 | 237 | 237 | 237 | 57 |
| **Median** | **29,000** | **24,979** | **53,402** | **19,811** | **88,500** |
| Minimum | 13,600 | 15,073 | 34,023 | 13,781 | 62,100 |
| Maximum | 46,400 | 43,066 | 74,936 | 31,439 | 159,600 |
| Lower quartile | 22,100 | 20,672 | 49,096 | 18,088 | 76,000 |
| Upper quartile | 35,400 | 34,023 | 62,016 | 22,395 | 98,100 |
| **Average** | **28,981** | **27,061** | **54,378** | **20,372** | **90,670** |
| Standard deviation | 7,933 | 7,818 | 9,116 | 3,730 | 19,929 |

## B) Greater mouse-eared bat (*M. myotis*): Call type B

Time-expanded calls of this call type sound similar to the squeaking of a rusty hinge. In the sonogram, they are characterised by a "wave-shaped" frequency modulation and the occurrence of several harmonics (Fig. 5.2.1.7 b). This "squeaky" call was exclusively recorded at various bat-boxes near Hohenecken when another Greater mouse-eared bat swarmed or entered the box. As shown in Table 5.2.1.7 b, the call duration varies between 40 ms and more than 600 ms, the peak frequency is approximately 17.6 kHz and the bandwidth of the first harmonic is 52.6 kHz (minimum: 7.3 kHz, maximum: 59.9 kHz).

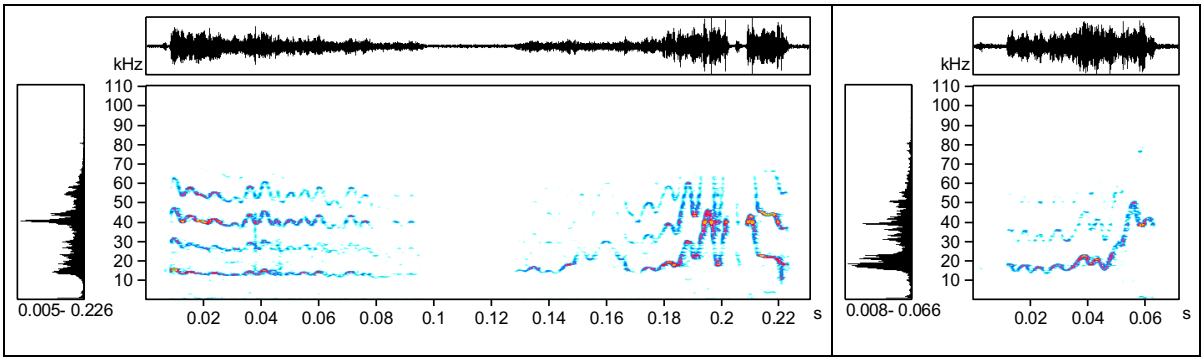


**Fig. 5.2.1.7 b:** Social calls of call type B from a mating roost of a Greater mouse-eared bat (*M. myotis*) during approach of another individual (Batbox near Hohenecken, 17 September 1999, 20:51 and 21:00)

**Tab. 5.2.1.7 b:** Statistical parameters of call type B from Greater mouse-eared bat (*M. myotis*)

| | Duration [ms] | $F_{max}$ [kHz] | $F_{start}$ [kHz] | $F_{end}$ [kHz] |
|---|---|---|---|---|
| Sample size | 19 | 19 | 19 | 19 |
| **Median** | **84,800** | **17,657** | **33,592** | **11,628** |
| Minimum | 40,100 | 11,628 | 14,643 | 7,321 |
| Maximum | 601,100 | 46,512 | 59,862 | 26,271 |
| Lower quartile | 57,500 | 15,073 | 19,380 | 10,767 |
| Upper quartile | 415,300 | 18,949 | 49,957 | 13,351 |
| **Average** | **214,926** | **18,745** | **35,156** | **12,557** |
| Standard deviation | 196,029 | 7,805 | 14,516 | 3,948 |

## C) Greater mouse-eared bat (*M. myotis*): Call type C

Social calls of call type C were among others recorded near Hohenecken. The calls were emitted from inside a batbox occupied by two Greater mouse-eared bats. The recording time was about half an hour after sunset, approximately 20 minutes before one of the bats left the roost. In addition, this sound was recorded inside the attic at Neumühle. In time expansion, this sounds like an elongated "scream" and consists of a CF element with a multiplicity of harmonics (Fig. 5.2.1.7 c) that are intermittently interrupted by broadband noise. The call duration varies from 63 ms to more than 320 ms and the median maximum frequency is 15.5 kHz (Tab. 5.2.1.7 c).

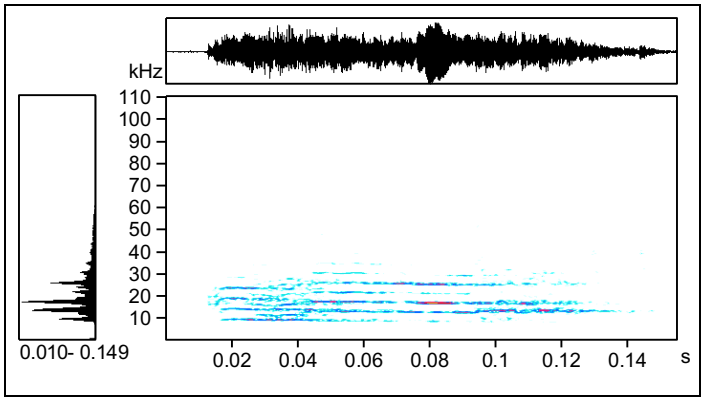


**Fig. 5.2.1.7 c:** Social calls (Call type C) from Greater mouse-eared bat (*M. myotis*) inside an attic (Neumühle, 25 July 2000, 20:58)

**Tab. 5.2.1.7 c:** Statistical parameters of call type C from Greater mouse-eared bat (*M. myotis*)

| | Duration [ms] | $F_{max}$ [kHz] |
|---|---|---|
| Sample size | 17 | 17 |
| **Median** | **136,100** | **15,504** |
| Minimum | 63,000 | 12,489 |
| Maximum | 326,600 | 18,519 |
| Lower quartile | 116,100 | 14,212 |
| Upper quartile | 228,100 | 16,365 |
| **Average** | **170,653** | **15,504** |
| Standard deviation | 89,198 | 1,530 |

## D) Greater mouse-eared bat (*M. myotis*): Call type D

The social calls of call type D, which are similar to those of the previous type C, were emitted in more or less regular call series. The calls were recorded exclusively inside the attic at Neumühle. Individual calls consist of a CF part with several harmonics or sub-harmonics being interrupted by silent periods of approximately 72 ms in median (Fig. 5.2.1.7 d). The call duration varies between 19 ms and 208 ms (median: 85.5 ms) and the median peak frequency is 16.8 kHz (Tab. 5.2.1.7 d).

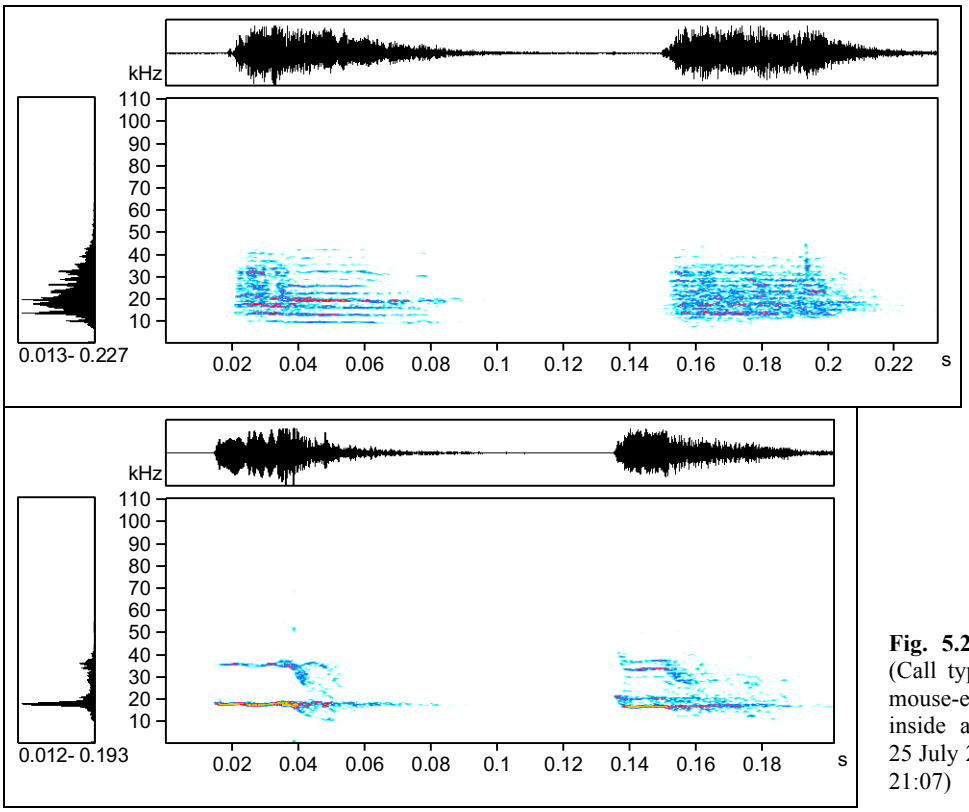


**Fig. 5.2.1.7 d:** Social calls (Call type D) from Greater mouse-eared bat (*M. myotis*) inside an attic (Neumühle, 25 July 2000, 21:04 Uhr and 21:07)

**Tab. 5.2.1.7 d:** Statistical parameters of call type D from Greater mouse-eared bat (*M. myotis*)

| | Duration [ms] | $F_{max}$ [kHz] | Call pauses [ms] |
|---|---|---|---|
| Sample size | 88 | 88 | 46 |
| **Median** | **85,500** | **16,796** | **71,700** |
| Minimum | 19,200 | 13,351 | 42,700 |
| Maximum | 208,400 | 22,825 | 151,500 |
| Lower quartile | 59,500 | 15,935 | 61,000 |
| Upper quartile | 124,950 | 17,657 | 82,400 |
| **Average** | **94,099** | **16,845** | **74,035** |
| Standard deviation | 43,653 | 1,655 | 18,582 |

## E) Greater mouse-eared bat (*M. myotis*): Call type E

Call type E is a "trill-like" call consisting of successively arranged, steeply falling modulated individual pulses (Fig. 5.2.1.7 e). The regular pulse intervals have a median duration of 15.1 ms and a call maximum of 31 kHz (Tab. 5.2.1.7 e). Call type E was recorded both inside the attic at Neumühle and from a batbox near Hohenecken. The recordings from the batbox, which was presumably used as a mating roost, took place on the 11th of September 2000 with two bats inside the box, right before one of them left the roost about 50 minutes after sunset and immediately after one animal entered the box about 2½ hours after sunset.

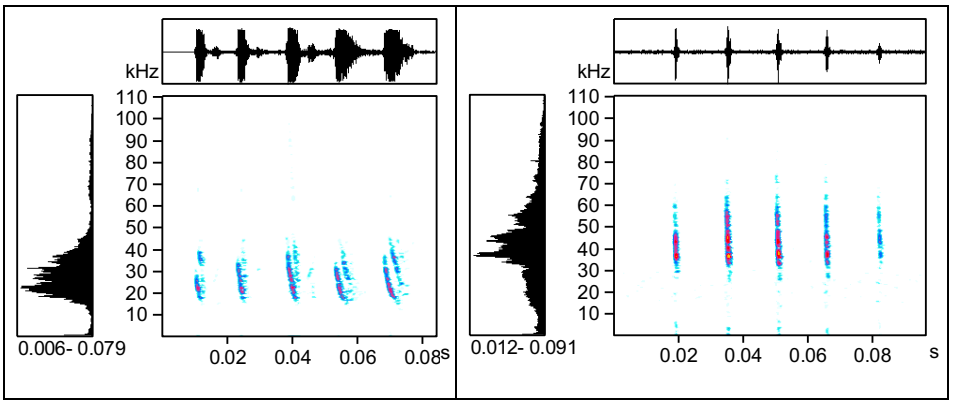


**Fig. 5.2.1.7 e:** Social calls of call type E from Greater mouse-eared bat (*M. myotis*) inside an attic (Neumühle, 25 July 2000, 21:39) and from a mating roost inside a batbox (Hohenecken, 11 September 2000, 20:37)

**Tab. 5.2.1.7 e:** Statistical parameters of call type E from Greater mouse-eared bat (*M. myotis*)

| | Duration [ms] | $F_{max}$ [kHz] | $F_{start}$ [kHz] | $F_{end}$ [kHz] | Pulse interval [ms] |
|---|---|---|---|---|---|
| Sample size | 54 | 54 | 54 | 54 | 157 |
| **Median** | **44,850** | **31,008** | **60,939** | **16,796** | **15,100** |
| Minimum | 16,800 | 24,979 | 42,205 | 8,613 | 10,200 |
| Maximum | 94,600 | 43,497 | 75,797 | 36,176 | 26,700 |
| Lower quartile | 32,200 | 28,855 | 53,402 | 14,643 | 13,600 |
| Upper quartile | 57,200 | 35,745 | 68,906 | 21,964 | 16,800 |
| **Average** | **46,222** | **32,364** | **60,261** | **18,479** | **15,812** |
| Standard deviation | 18,408 | 4,532 | 9,277 | 5,928 | 3,221 |

## F) Greater mouse-eared bat (*M. myotis*): Call type F

Calls of call type F (Fig. 5.2.1.7 f) differ from those of call type E by the significantly shorter pulse intervals between the FM elements (median: 10.2 ms). This social call was recorded from Greater mouse-eared bats caught by mist netting inside an underground winter roost as well as in the maternity colony from the attic at Neumühle, and at different mating roosts near Hohenecken. The calls were always emitted from inside the batboxes with other Greater mouse-eared bats swarming nearby, or approaching respectively, entering the roost. The call duration is between 19 ms and 220 ms and the median peak frequency is about 35 kHz (Tab. 5.2.1.7 f).

**Tab. 5.2.1.7 f:** Statistical parameters of call type F from Greater mouse-eared bat (*M. myotis*)

| | Duration [ms] | $F_{max}$ [kHz] | $F_{start}$ [kHz] | $F_{end}$ [kHz] | Pulse interval [ms] |
|---|---|---|---|---|---|
| Sample size | 35 | 35 | 35 | 35 | 286 |
| **Median** | **55,100** | **35,315** | **56,848** | **19,380** | **10,200** |
| Minimum | 18,900 | 30,147 | 46,942 | 14,643 | 6,400 |
| Maximum | 221,800 | 42,205 | 68,476 | 31,869 | 19,400 |
| Lower quartile | 43,000 | 33,161 | 52,972 | 17,657 | 9,600 |
| Upper quartile | 162,200 | 36,176 | 63,308 | 22,395 | 10,700 |
| **Average** | **87,723** | **34,835** | **57,377** | **20,573** | **10,459** |
| Standard deviation | 65,929 | 2,504 | 5,424 | 4,540 | 1,715 |

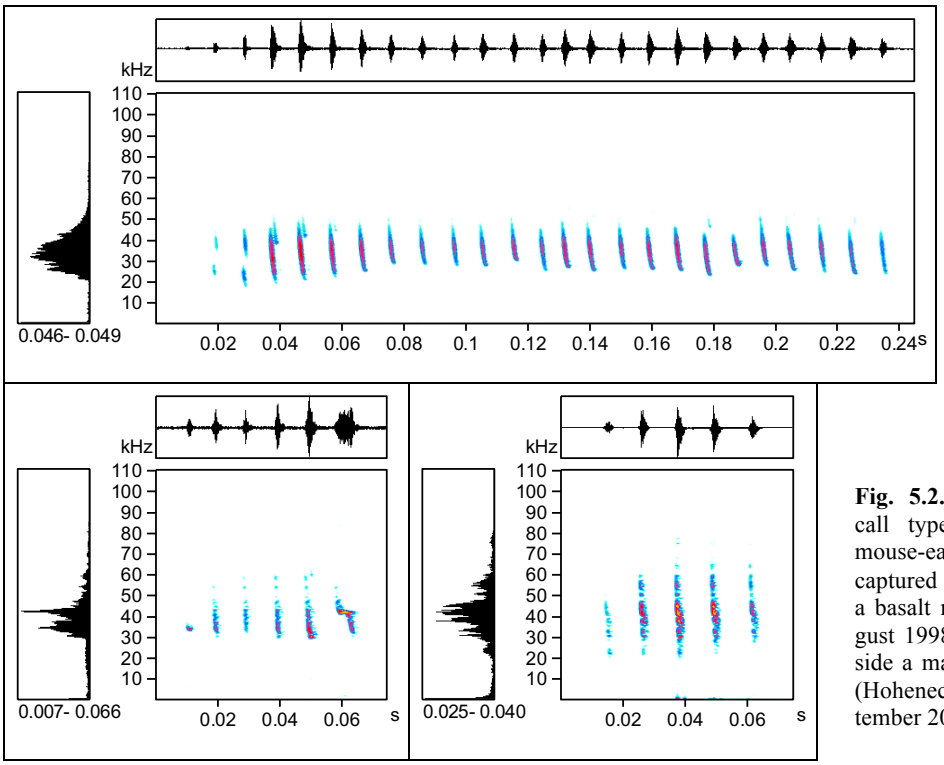


**Fig. 5.2.1.7 f:** Social calls of call type F from a Greater mouse-eared bat (*M. myotis*) captured by mist netting inside a basalt mine (Mendig, 21 August 1998, 21:23) and from inside a mating roost in a batbox (Hohenecken, 16 and 17 September 2000, 21:58 and 21:00)

## 5.2.1.8 Noctule (*Nyctalus noctula*, SCHREBER, 1774)

Within the scope of the present work, the majority of the social calls from *N. noctula* were recorded at Kaiserslautern Vogelwoog (KL 1 - KL 3) inside foraging areas above the waters and over a meadow as well as from tree roosts discovered there during this work (cf. Fig. 5.1.2 b1). A few recordings took place at a forest area near Stelzenberg (LA 1) as well as from Gießen "Philosophenwald". 1,522 individual calls from the Noctule bat were analysed and eleven call types were described.

### A) Noctule (*N. noctula*): Call type A

One of the most striking vocalizations of the Noctule bat is call type A, which can also be heard without a detector. It was mostly recorded at various tree roosts during the mating period between August and October – with an exception also in May. Usually, the echolocation calls of far away by-passing Noctules were also heard on the recordings. This call type was never recorded in a flying animal; the sounds were always emitted from the roosts. 246 calls were evaluated. These are hardly modulated, nearly constant-frequency sounds with a duration of 30 - 90 ms (median: 57.5 ms) and a median peak frequency of 13.8 kHz (11.6 - 16.8 kHz). Occasionally, the calls are slightly rising at the beginning and then slowly downward modulated. The median of the highest frequency is 15.7 kHz and the lowest frequency is 10.3 kHz. The sounds are emitted in call series with median call intervals of 2.8 seconds. This corresponds to a repetition rate of 0.35 Hz (Fig. and Tab. 5.2.1.8 a).

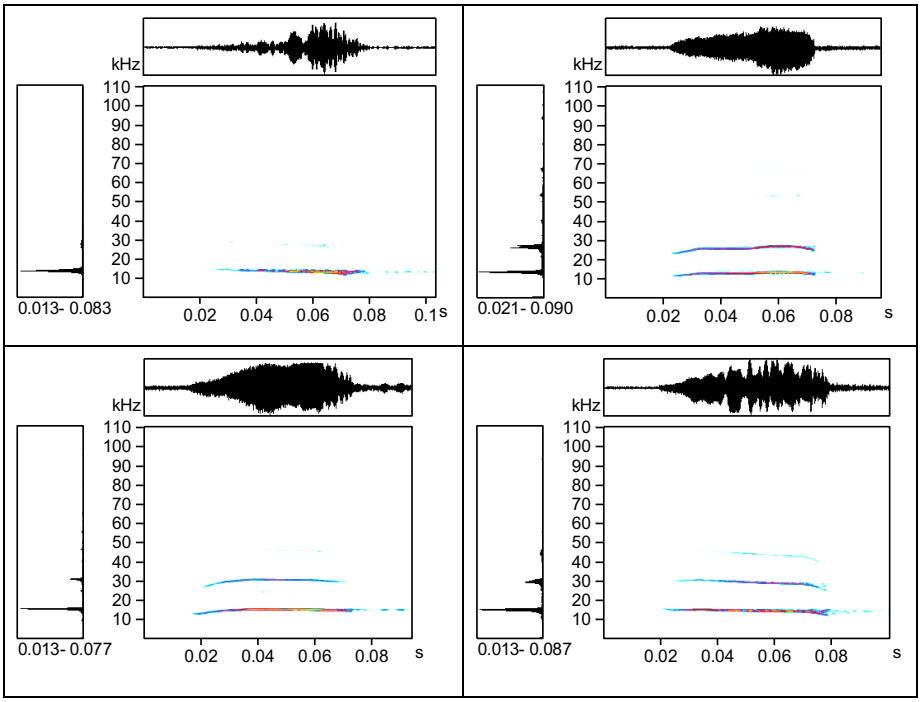


**Fig. 5.2.1.8 a:** Stationary social calls of the Noctule (*N. noctula*) from the roost (Call type A) (Left above: Kaiserslautern Vogelwoog, 15 Mai 2000 at tree roost No. 1, 22:17; Right above: 12 August 1998 over a meadow near Erzhütten, 23:30 (suspected roost nearby); Left below: 9 August 2000 at tree roost No. 5, 23:12; Right below: 23 September 1999 at tree roost No. 3, 20:53)

**Tab. 5.2.1.8 a:** Statistical parameters of call type A from the Noctule (*N. noctula*)

| | Duration [ms] | $F_{max}$ [kHz] | $F_{start}$ [kHz] | $F_{end}$ [kHz] | Call intervals [s] |
|---|---|---|---|---|---|
| Sample size | 246 | 246 | 246 | 246 | 62 |
| **Median** | **57,500** | **13,781** | **15,719** | **10,336** | **2,805** |
| Minimum | 31,300 | 11,628 | 12,920 | 8,613 | 1,024 |
| Maximum | 90,600 | 16,796 | 25,409 | 14,643 | 4,216 |
| Lower quartile | 53,100 | 13,351 | 15,073 | 9,905 | 2,470 |
| Upper quartile | 61,200 | 14,212 | 16,796 | 11,197 | 3,368 |
| **Average** | **56,900** | **13,986** | **16,230** | **10,676** | **2,831** |
| Standard deviation | 8,315 | 0,805 | 1,822 | 0,906 | 0,602 |

## B) Noctule (*N. noctula*): Call type B

At four mating roosts, "double calls" were recorded during periods of particularly high call activity and in the case of distant flybys (Fig. 5.2.1.8 b). Two call elements, which are initially steeply downward modulated and end with a flat end portion, are emitted one after another. The call duration varies between 29 ms and 68.2 ms (median: 46.1 ms) and the peak frequency is about 16 kHz. The calls cover a frequency range of approximately 13 - 28 kHz (minimum-maximum values: 11.2 - 36.6 kHz). The silent period between the call elements is 2.9 - 11.6 ms (median: 6.7 ms). Usually the first call element is longer than the second is (Tab. 5.2.1.8 b).

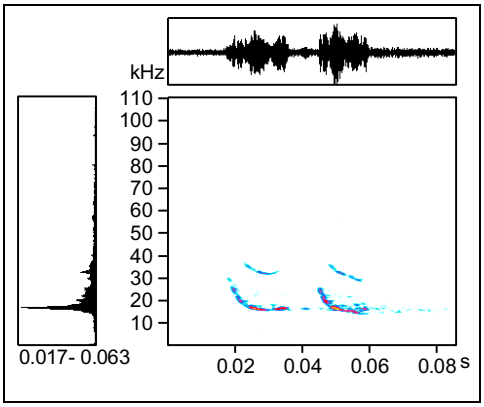


**Fig. 5.2.1.8 b:** "Double call" (Call type B) from the Noctule (*N. noctula*) emitted stationary from tree roost No. 5 (Vogelwoog, 9 August 2000, 22:46)

**Tab. 5.2.1.8 b:** Statistical parameters of call type B from the Noctule (*N. noctula*)

| | Duration [ms] | $F_{max}$ [kHz] | $F_{start}$ [kHz] | $F_{end}$ [kHz] | Duration 1 pulse [ms] | $F_{max}$ 1 pulse [kHz] | $F_{end}$ 1 pulse [kHz] | Duration 2 pulse [ms] | $F_{max}$ 2 pulse [kHz] | $F_{end}$ 2 pulse [kHz] | Intervals [ms] |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Sample size | 25 | 25 | 25 | 25 | 25 | 25 | 25 | 25 | 25 | 25 | 25 |
| **Median** | **46,100** | **15,935** | **27,993** | **13,351** | **23,200** | **15,935** | **13,781** | **16,800** | **15,935** | **13,351** | **6,700** |
| Minimum | 29,000 | 13,781 | 16,796 | 11,197 | 16,300 | 13,351 | 11,628 | 6,700 | 14,212 | 11,197 | 2,900 |
| Maximum | 68,200 | 18,949 | 36,606 | 15,504 | 35,700 | 17,657 | 15,073 | 24,700 | 18,949 | 16,365 | 11,600 |
| Lower quartile | 41,500 | 15,073 | 23,256 | 12,059 | 20,000 | 15,073 | 12,920 | 14,200 | 15,073 | 12,489 | 4,600 |
| Upper quartile | 50,500 | 16,365 | 31,439 | 13,781 | 25,000 | 16,796 | 14,212 | 22,100 | 16,796 | 14,643 | 8,100 |
| **Average** | **47,076** | **15,814** | **26,960** | **13,109** | **23,608** | **15,831** | **13,557** | **17,772** | **15,986** | **13,557** | **6,716** |
| Standard deviation | 9,250 | 1,163 | 5,201 | 1,160 | 5,596 | 1,012 | 1,003 | 4,901 | 1,245 | 1,450 | 2,325 |

## C) Noctule (*N. noctula*): Call type C

As well as call types A and B, this call sequence, referred to here as call type C, was also registered in periods of particularly high call activity and in combination with other call types. The fourth, sometimes also the third and fourth call element may be missing. The complete, time-expanded sequence reminds the listener of the beginning of a rising scale. The call sequence shows a transition from constant-frequency, elongated to downward frequency-modulated, shorter call elements (Fig. 5.2.1.8 c). As shown in Table 5.2.1.8 c, the succeeding single pulses decrease in duration (median: 57,2 ms → 47,3 ms → 33,3 ms → 18,6 ms) and the values for $F_{max}$, $F_{anf}$ and $F_{end}$ increase continuously (median $F_{max}$: 13,6 kHz → 13,8 kHz → 16,2 kHz → 18,5 kHz).

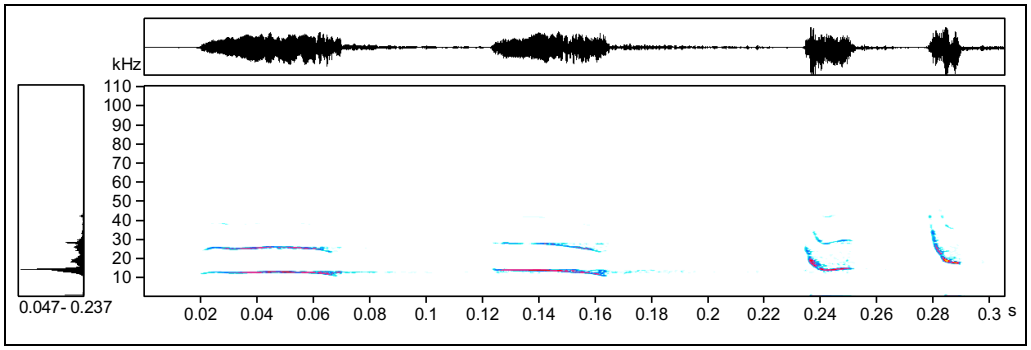


**Fig. 5.2.1.8 c:** Call type C from the Noctule (*N. noctula*) – here emitted stationary from tree roost No. 4 (Vogelwoog, 27 August 1999, 5:33) – reminds of a scale

**Tab. 5.2.1.8 c:** Statistical parameters of call type C from the Noctule (*N. noctula*)

| | Duration 1 elem [ms] | $F_{max}$ 1 elem [kHz] | $F_{start}$ 1 elem [kHz] | $F_{end}$ 1 elem [kHz] | Duration 2 elem [ms] | $F_{max}$ 2 elem [kHz] | $F_{start}$ 2 elem [kHz] | $F_{end}$ 2 elem [kHz] |
|---|---|---|---|---|---|---|---|---|
| Sample size | 20 | 20 | 20 | 20 | 20 | 20 | 20 | 20 |
| **Median** | **57,200** | **13,566** | **15,073** | **9,905** | **47,300** | **13,781** | **16,150** | **10,551** |
| Minimum | 41,500 | 10,767 | 12,920 | 9,044 | 19,200 | 12,489 | 14,212 | 9,044 |
| Maximum | 70,800 | 14,643 | 16,365 | 10,767 | 75,500 | 15,935 | 21,964 | 14,643 |
| Lower quartile | 52,950 | 13,135 | 14,643 | 9,475 | 44,100 | 13,566 | 15,289 | 9,905 |
| Upper quartile | 59,500 | 13,997 | 15,719 | 10,336 | 52,800 | 14,212 | 17,227 | 11,628 |
| **Average** | **56,400** | **13,523** | **15,116** | **9,841** | **47,805** | **14,018** | **16,559** | **10,960** |
| Standard deviation | 6,407 | 0,866 | 0,801 | 0,546 | 12,575 | 0,844 | 1,998 | 1,534 |

| | Duration 3 elem [ms] | $F_{max}$ 3 elem [kHz] | $F_{start}$ 3 elem [kHz] | $F_{end}$ 3 elem [kHz] | Duration 4 elem [ms] | $F_{max}$ 4 elem [kHz] | $F_{start}$ 4 elem [kHz] | $F_{end}$ 4 elem [kHz] |
|---|---|---|---|---|---|---|---|---|
| Sample size | 10 | 10 | 10 | 10 | 5 | 5 | 5 | 5 |
| **Median** | **33,250** | **16,150** | **25,194** | **13,781** | **18,600** | **18,519** | **33,592** | **17,227** |
| Minimum | 13,400 | 14,212 | 15,504 | 11,197 | 16,500 | 17,657 | 23,687 | 14,643 |
| Maximum | 57,500 | 18,519 | 39,190 | 17,227 | 36,000 | 21,103 | 44,358 | 18,949 |
| Lower quartile | 19,200 | 14,643 | 18,949 | 12,059 | 17,100 | 17,657 | 27,993 | 15,504 |
| Upper quartile | 37,400 | 16,796 | 31,869 | 15,935 | 26,400 | 20,241 | 35,315 | 18,519 |
| **Average** | **31,180** | **16,064** | **25,926** | **13,954** | **22,920** | **19,035** | **32,989** | **16,968** |
| Standard deviation | 13,768 | 1,586 | 7,904 | 2,131 | 8,321 | 1,565 | 7,851 | 1,867 |

## D) Noctule (*N. noctula*): Call type D

Call type D was emitted in short call series from inside the roosts or from flying Noctule bats. At roosting sites, approach flights or bats entering the roost were frequently observed. In the case of Noctules in flight, call type D was usually recorded when two animals encountered each other in the foraging area. The calls start with a steeply downward FM part, which flattens off approximately from the center of the call and merges into a flat downward, almost linear-period-modulated, end part. The comparatively loud calls show one or more harmonics in the sonogram (Fig. 5.2.1.8 d). The peak frequency is clearly in the range audible to humans (median: 15.1 kHz) and a frequency range of approximately 32 - 11 kHz (maximum values: 50.8 - 9.0 kHz) is covered. The silent periods between the single call elements have a duration of about 40 ms (Tab. 5.2.1.8 d).

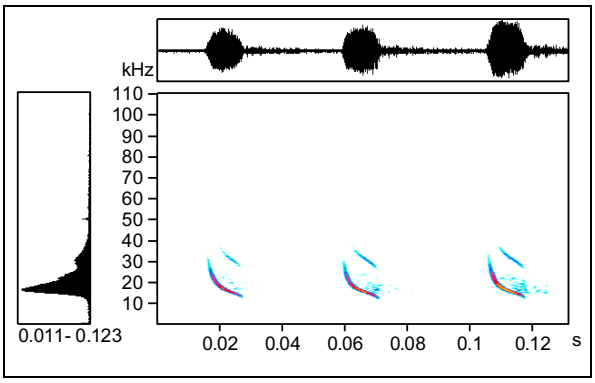


**Fig. 5.2.1.8 d:** Series of social calls (Call type D) from the Noctule (*N. noctula*) emitted in flight during the encounter of two animals in the foraging area (Kaiserslautern Vogelwoog, 20 June 2000, 22:46)

**Tab. 5.2.1.8 d:** Statistical parameters of call type D from the Noctule (*N. noctula*)

| | Duration [ms] | $F_{max}$ [kHz] | $F_{start}$ [kHz] | $F_{end}$ [kHz] | Call pauses [ms] |
|---|---|---|---|---|---|
| Sample size | 111 | 111 | 111 | 111 | 87 |
| **Median** | **15,100** | **15,504** | **32,300** | **10,767** | **39,800** |
| Minimum | 8,700 | 12,920 | 18,519 | 9,044 | 26,400 |
| Maximum | 31,100 | 18,949 | 50,818 | 17,227 | 81,600 |
| Lower quartile | 13,100 | 14,643 | 25,840 | 10,336 | 32,500 |
| Upper quartile | 18,600 | 16,365 | 39,621 | 11,628 | 43,500 |
| **Average** | **15,807** | **15,558** | **32,851** | **11,019** | **41,191** |
| Standard deviation | 4,075 | 1,200 | 8,271 | 1,136 | 12,108 |

## E) Noctule (*N. noctula*): Call type E

Call type E includes social calls which have a certain similarity to frequency-modulated echolocation calls, such as those emitted by Noctules moving in an obstacle-rich airspace. These "echolocation-like" calls could only be heard in the mating period at different tree roosts during particularly high call activity. The constant loudness of the calls, their structure in the sonogram and their consecutiveness considered in the context of the respective recording sequence, as well as the lack

of visual observations of flying animals (despite night vision equipment) show that these calls must have been emitted from inside the roost by the roost-holder. The 288 single calls measured could again be differentiated into three subtypes, but there are also fluent transitions between these groups. Respectively, the calls show a more or less steeply downwards modulated FM structure, sometimes with a flattened end part (Figures 5.2.1.8 e1 - e3).

### E.1) Call type E 1

The call duration of these low-frequency calls is 11.3 ms in median. With a peak frequency of around 16 kHz and lowest frequencies ($F_{end}$) of about 12 kHz, they are clearly audible to humans. The highest frequency is at a maximum of 50.8 kHz (Tab. 5.2.1.8 e1).

### E.2) Call type E 2

The calls of call type E 2 are steeply downwards modulated, like those of call type E 1. However, the flattening at the end of the call is only very weak or completely absent. The call duration is 9.3 ms in the median. The call maximum (median: 19.4 kHz) and the final frequency (median: 13.8 kHz) are still within the audible range. The initial frequency shows a maximum of 57.3 kHz (Tab. 5.2.1.8 e2).

### E.3) Call type E 3

The steep FM calls of this call type have a duration of about 6.1 ms in median. So, with a peak frequency of around 30 kHz and end frequencies around 24 kHz, these calls are completely outside the human frequency range. Even though the lowest measured end frequency is 18.5 kHz, the call duration is less than 10 ms and therefore the calls are not perceivable without detector. The highest frequency is 63.3 kHz (Tab. 5.2.1.8 e3). Occasionally, the calls merge into call type F described below.

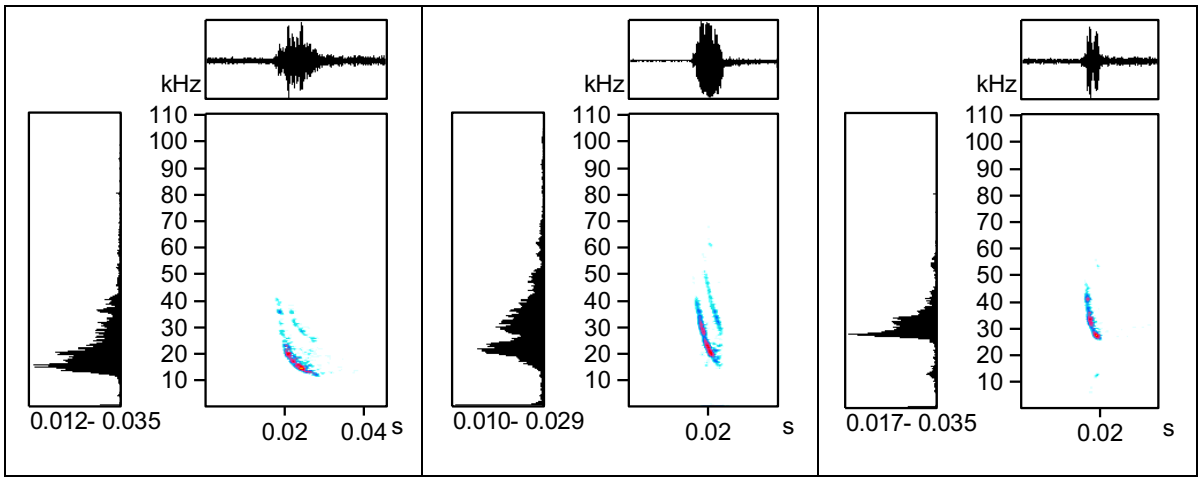


**Fig. 5.2.1.8 e1:** "Echolocation-like" social call emitted from inside a roost (Call type E 1) from the Noctule (*N. noctula*) (Kaiserslautern Vogelwoog,

**Fig. 5.2.1.8 e2:** "Echolocation-like" social call (Call type E 2) from the Noctule (*N. noctula*) in the audible frequency range (Kaiserslautern

**Fig. 5.2.1.8 e3:** "Echolocation-like" social call (Call type E 3) from the Noctule (*N. noctula*) above the human frequency range (Kaiserslautern

tree roost No. 4, 30 September 1999, 20:14 Uhr) | Vogelwoog, tree roost No. 3, 28 September 2000, 21:03 Uhr) | Vogelwoog, tree roost No. 4, 27 August 1999, 5:00 Uhr)

**Tab. 5.2.1.8 e1:** Statistical parameters of call type E 1 from the Noctule (*N. noctula*)

| | Duration [ms] | $F_{max}$ [kHz] | $F_{start}$ [kHz] | $F_{end}$ [kHz] |
|---|---|---|---|---|
| Sample size | 75 | 75 | 75 | 75 |
| **Median** | **11,300** | **15,935** | **42,205** | **12,059** |
| Minimum | 5,800 | 13,351 | 23,687 | 9,905 |
| Maximum | 30,800 | 18,519 | 50,818 | 16,796 |
| Lower quartile | 9,600 | 15,504 | 37,037 | 11,197 |
| Upper quartile | 13,900 | 16,796 | 44,358 | 13,351 |
| **Average** | **12,385** | **15,894** | **40,540** | **12,317** |
| Standard deviation | 4,704 | 1,067 | 5,594 | 1,540 |

**Tab. 5.2.1.8 e2:** Statistical parameters of call type E 2 from the Noctule (*N. noctula*)

| | Duration [ms] | $F_{max}$ [kHz] | $F_{start}$ [kHz] | $F_{end}$ [kHz] |
|---|---|---|---|---|
| Sample size | 152 | 152 | 152 | 152 |
| **Median** | **9,300** | **19,380** | **40,913** | **13,781** |
| Minimum | 5,200 | 16,796 | 24,548 | 10,336 |
| Maximum | 29,300 | 23,256 | 57,278 | 18,949 |
| Lower quartile | 7,800 | 18,519 | 35,745 | 12,059 |
| Upper quartile | 11,600 | 20,241 | 43,928 | 15,073 |
| **Average** | **10,186** | **19,471** | **39,845** | **13,716** |
| Standard deviation | 3,665 | 1,258 | 5,934 | 1,971 |

**Tab. 5.2.1.8 e3:** Statistical parameters of call type E 3 from the Noctule (*N. noctula*)

| | Duration [ms] | $F_{max}$ [kHz] | $F_{start}$ [kHz] | $F_{end}$ [kHz] |
|---|---|---|---|---|
| Sample size | 61 | 61 | 61 | 61 |
| **Median** | **6,100** | **29,716** | **47,804** | **24,117** |
| Minimum | 3,200 | 26,701 | 34,453 | 18,519 |
| Maximum | 10,200 | 34,023 | 63,308 | 28,855 |
| Lower quartile | 5,200 | 29,285 | 41,774 | 22,825 |
| Upper quartile | 7,500 | 30,577 | 51,249 | 25,409 |
| **Average** | **6,277** | **30,055** | **46,999** | **24,145** |
| Standard deviation | 1,655 | 1,523 | 6,791 | 2,199 |

## F) Noctule (*N. noctula*): Call type F

Call type F reminds of a "final buzz" and was also emitted by Noctules from inside the roost or from individuals sitting at the entrance of a tree hole. Typically, this call type was registered in periods of high call activity in combination with "echolocation like" sounds and other call types.

For the reasons mentioned in chapter E, these calls, as well as those from call type E, do not originate from animals in flight. The call sequences consist of a series of successive, very steep and short FM pulses (Fig. 5.2.1.8 f). The pulse intervals become increasingly shorter at the beginning of the call, then remain relatively constant (median: 10.7 ms) and become longer at the end of the call. The call sequences vary considerabely in duration and may persist for more than one second (maximum: 1,287.6 ms). Call type F (median $F_{max}$: 32.9 kHz) can not be perceived without a detector, thus being completely outside the human audible range (Tab. 5.2.1.8 f).

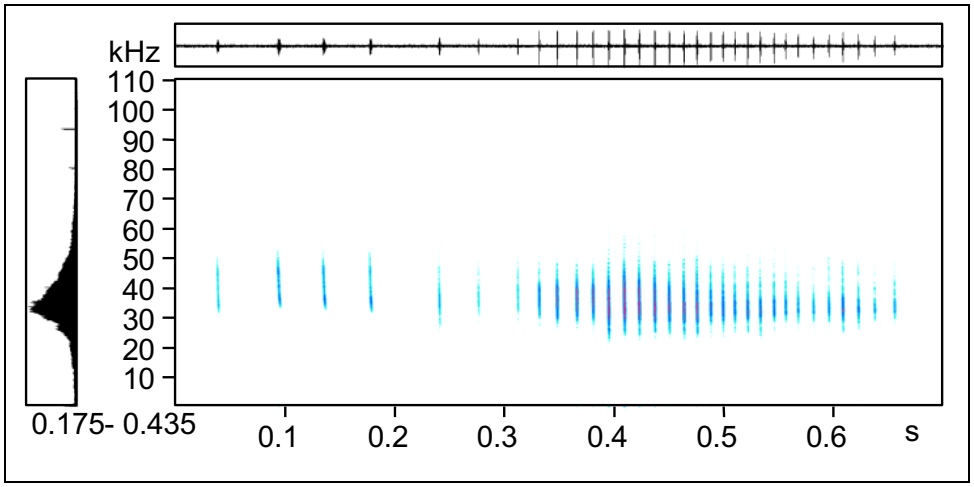


**Fig. 5.2.1.8 f:** Social call of type F from a Noctule (*N. noctula*) in a tree roost (Kaiserslautern Vogelwoog, tree roost No. 5, 24 August 2000, 21:38; Note on the display mode: The resolution of the time axis is compressed by selecting an FFT length of 1,024)

**Tab. 5.2.1.8 f:** Statistical parameters of call type F from the Noctule (*N. noctula*)

| | Duration [ms] | $F_{max}$ [kHz] | Pulse interval [ms] |
|---|---|---|---|
| Sample size | 13 | 14 | 434 |
| **Median** | **397,600** | **32,946** | **10,700** |
| Minimum | 82,100 | 29,715 | 6,100 |
| Maximum | 1287,600 | 40,052 | 78,100 |
| Lower quartile | 230,700 | 30,147 | 9,000 |
| Upper quartile | 624,000 | 37,467 | 14,800 |
| **Average** | **464,754** | **34,330** | **14,185** |
| Standard deviation | 324,939 | 4,122 | 9,919 |

## G) Noctule (*N. noctula*): Call type G

This very conspicuous call type was recorded from flying Noctules as well as from individuals sitting in the roost. It usually came from direct interactions of two animals (encounters in the foraging area, "pursuit flights", swarming in front of the roost, etc.). In the sonogram, the calls show a sinusoidal modulation between 24.1 and 10.3 kHz (median values of 117 analysed calls). One or more harmonics usually occur (Fig. 5.2.1.8 g). The call duration varies between 40 ms and 160 ms (median: 81.6 ms) and the median of the peak frequency is 17.7 kHz (Tab. 5.2.1.8 g). The time-expanded calls resemble a "purring trill". Without a detector, they sound like a piercing chirp.

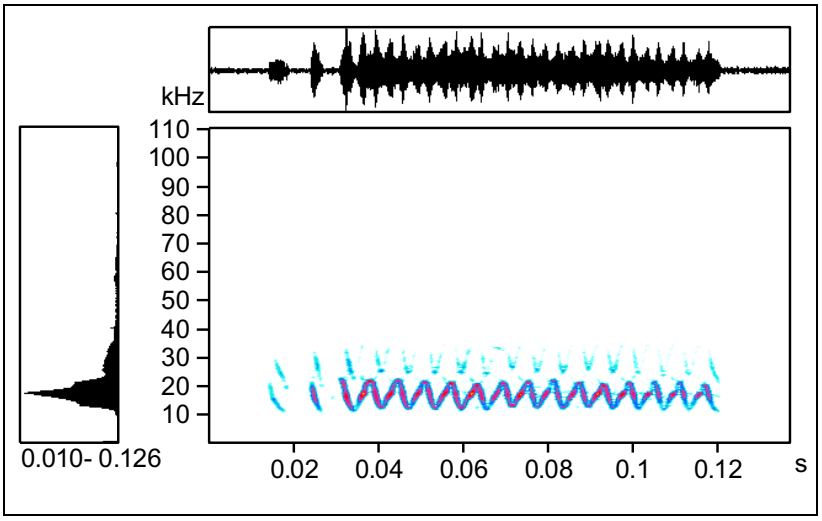


**Fig. 5.2.1.8 g:** Social call of call type G from the Noctule (*N. noctula*) during a "pursuit flight" of two animals, flying from the lakeshore of Vogelwoog into the adjacent stock of trees (Kaiserslautern Vogelwoog, 10 August 1998, 21:33, a pine with a suspected tree roost was cut there in winter 1998/99)

**Tab. 5.2.1.8 g:** Statistical parameters of call type G from the Noctule (*N. noctula*)

| | Duration [ms] | $F_{max}$ [kHz] | $F_{start}$ [kHz] | $F_{end}$ [kHz] |
|---|---|---|---|---|
| Sample size | 117 | 113 | 117 | 117 |
| **Median** | **81,600** | **17,657** | **24,117** | **10,336** |
| Minimum | 40,300 | 11,197 | 16,796 | 8,183 |
| Maximum | 162,200 | 22,825 | 37,898 | 14,643 |
| Lower quartile | 67,900 | 17,227 | 21,964 | 9,905 |
| Upper quartile | 105,100 | 18,949 | 26,271 | 11,197 |
| **Average** | **86,551** | **17,821** | **24,279** | **10,649** |
| Standard deviation | 24,276 | 1,916 | 3,783 | 1,295 |

## H) Noctule (*N. noctula*): Call type H

Social calls of type H will be specifically in the focus of attention in chapter 5.2.3.2 [*note from the author: This chapter deals with the intraspecific variability of mating calls from individual Noctule bats. Later on in the thesis, the interindividual variability of call type H is interpreted as a kind of individual "acoustic fingerprint" permitting mutual recognition*]. These very "melodious" and variable calls are characterised here as "chirping" due to the auditory impression when replayed with tenfold time expansion. They contain between two and seven call elements, including always pulses with "V-shaped" frequency modulation. In general, the first call element differs from the following in frequency response and peak frequency. Usually, the final call element is a steeply downward-modulated FM pulse. Figure 5.2.1.8 h1 shows four of the approximately 20 recorded call variants of call type H (see further sonograms in chapter 5.2.3.2.2). The calls were emitted both from inside the roost and in flight, whereby interactions between different individuals could often be observed.

Table 5.2.1.8 h1 shows the statistical parameters of 464 single measured calls of this call type. The duration of the calls varies between 31 ms and 123 ms (median: 57.5 ms) and the median peak frequency of the total call is 25.6 kHz. They cover a frequency range of approximately 47.8 -

20.7 kHz (maximum-minimum values: 68 - 14.2 kHz). Rarely, the calls or at least parts of them are in the human auditory range. The first call element generally shows the lowest frequency values (median $F_{max}$: 24.5 kHz, median $F_{end}$: 22.4 kHz). The following call elements show, on average, higher frequencies with values of $F_{max}$ and $F_{end}$ decreasing towards the end of the call. Table 5.2.1.8 h2 clarifies that the great variability in the call duration is mainly due to the different number of call elements being used.

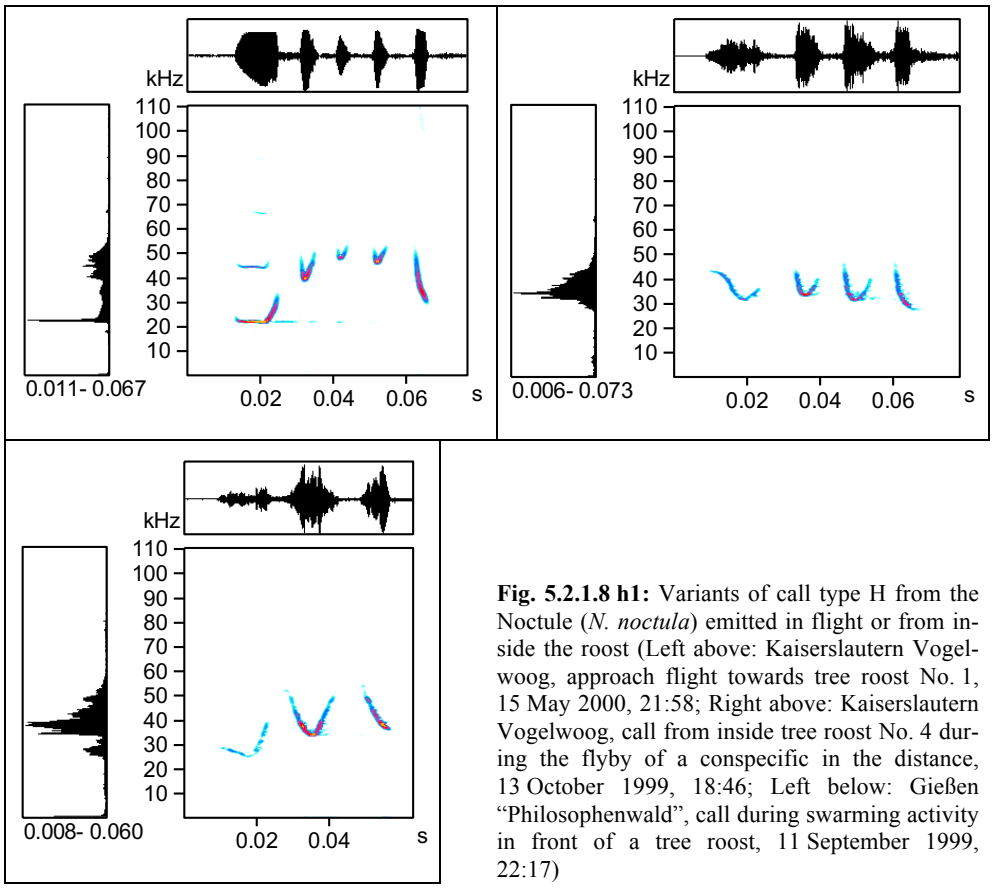


**Fig. 5.2.1.8 h1:** Variants of call type H from the Noctule (*N. noctula*) emitted in flight or from inside the roost (Left above: Kaiserslautern Vogelwoog, approach flight towards tree roost No. 1, 15 May 2000, 21:58; Right above: Kaiserslautern Vogelwoog, call from inside tree roost No. 4 during the flyby of a conspecific in the distance, 13 October 1999, 18:46; Left below: Gießen "Philosophenwald", call during swarming activity in front of a tree roost, 11 September 1999, 22:17)

To some extent, social calls of call type H have also been registered as "composite" social calls in combination with the already described call type G. These vocalisations start like an ordinary "H-call" but then merging into a downstream "G-Trill" (Fig. 5.2.1.8 h2).

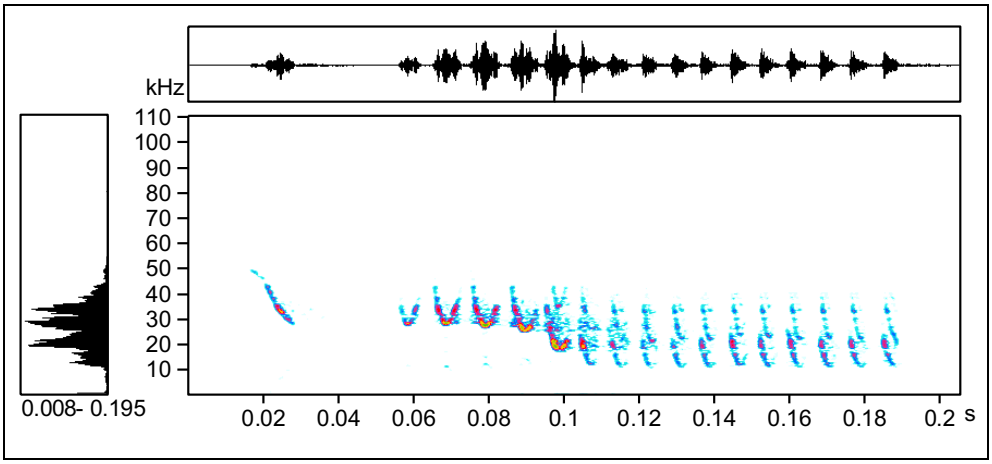


**Fig. 5.2.1.8 h2:** Variant of call type H from the Noctule (*N. noctula*) in combination with the low-frequency "trill" of call type G (Vogelwoog, tree cavity No. 4, 27 August 1999, 22:13)

**Tab. 5.2.1.8 h1:** Statistical parameters of call type H from the Noctule (*N. noctula*)

| | Duration [ms] | $F_{max}$ [kHz] | $F_{start}$ [kHz] | $F_{end}$ [kHz] | | |
|---|---|---|---|---|---|---|
| Sample size | 461 | 464 | 451 | 464 | | |
| **Median** | **57,500** | **25,625** | **47,804** | **20,672** | | |
| Minimum | 31,100 | 16,365 | 26,271 | 14,212 | | |
| Maximum | 122,500 | 39,621 | 68,045 | 28,855 | | |
| Lower quartile | 49,900 | 22,825 | 43,497 | 18,088 | | |
| Upper quartile | 66,800 | 30,147 | 51,249 | 24,548 | | |
| **Average** | **59,034** | **26,407** | **47,285** | **21,114** | | |
| Standard deviation | 13,901 | 4,894 | 6,963 | 3,634 | | |
| | | | | | | |
| | $F_{max}$ 1 pulse [kHz] | $F_{max}$ 2 pulse [kHz] | $F_{max}$ 3 pulse [kHz] | $F_{max}$ 4 pulse [kHz] | $F_{max}$ 5 pulse [kHz] | $F_{max}$ 6 pulse [kHz] |
| Sample size | 439 | 443 | 431 | 326 | 175 | 155 |
| **Median** | **24,548** | **29,285** | **29,716** | **29,285** | **28,424** | **28,855** |
| Minimum | 15,504 | 18,519 | 18,088 | 17,227 | 17,227 | 19,380 |
| Maximum | 43,497 | 46,081 | 49,526 | 50,818 | 41,344 | 36,176 |
| Lower quartile | 21,103 | 22,825 | 24,548 | 24,548 | 25,409 | 27,132 |
| Upper quartile | 28,424 | 32,300 | 34,023 | 33,161 | 30,147 | 30,147 |
| **Average** | **25,411** | **28,132** | **30,227** | **29,802** | **27,855** | **28,338** |
| Standard deviation | 5,615 | 5,452 | 6,819 | 7,012 | 5,059 | 2,966 |
| | | | | | | |
| | $F_{end}$ 1 pulse [kHz] | $F_{end}$ 2 pulse [kHz] | $F_{end}$ 3 pulse [kHz] | $F_{end}$ 4 pulse [kHz] | $F_{end}$ 5 pulse [kHz] | $F_{end}$ 6 pulse [kHz] |
| Sample size | 439 | 442 | 430 | 322 | 170 | 155 |
| **Median** | **22,395** | **27,132** | **27,563** | **27,132** | **26,701** | **25,409** |
| Minimum | 14,212 | 16,796 | 15,504 | 15,073 | 15,504 | 16,365 |
| Maximum | 31,008 | 45,220 | 48,234 | 45,220 | 38,760 | 34,453 |
| Lower quartile | 18,949 | 21,533 | 22,825 | 22,395 | 23,687 | 23,687 |
| Upper quartile | 26,271 | 29,716 | 30,577 | 29,285 | 27,563 | 26,271 |
| **Average** | **22,595** | **26,129** | **27,923** | **27,121** | **25,488** | **24,837** |
| Standard deviation | 4,146 | 5,147 | 6,617 | 6,467 | 4,902 | 2,916 |

**Tab. 5.2.1.8 h2:** Call duration of call type H from the noctule (*N. noctula*) as a function of the number of call elements being used

| | Duration 2 elements [ms] | Duration 3 elements [ms] | Duration 4 elements [ms] | Duration 5 elements [ms] | Duration 6 elements [ms] |
|---|---|---|---|---|---|
| Sample size | 17 | 96 | 134 | 115 | 88 |
| **Median** | **38,300** | **48,650** | **55,000** | **59,500** | **72,900** |
| Minimum | 34,200 | 31,100 | 38,300 | 40,600 | 57,500 |
| Maximum | 52,800 | 82,400 | 77,200 | 122,500 | 116,400 |
| Lower quartile | 36,000 | 43,800 | 49,600 | 54,600 | 69,700 |
| Upper quartile | 46,700 | 54,250 | 61,500 | 66,200 | 79,850 |
| **Average** | **41,688** | **50,646** | **55,351** | **61,616** | **75,623** |
| Standard deviation | 6,588 | 11,598 | 7,925 | 11,354 | 10,778 |

## I) Noctule (*N. noctula*): Call type I

The call types I and J were emitted from the roost occupant of tree roost No. 4 after an individual from tree roost No. 2 had entered. Except on this occasion, calls of the call type I were invariably recorded at occupied tree roosts at dusk or in the early morning hours from about two hours before sunrise. The calls could only be registered during the period of late summer/autumn, which is the mating period of the Noctule. These are series of low-frequency call sequences, each consisting of two to four flat-modulated single elements (Fig. 5.2.1.8 i). The call duration is about 20 - 85 ms (median: 40.1 ms), the peak frequency is 18.5 kHz and the lowest frequency $F_{end}$ is 15.1 kHz (Tab. 5.2.1.8 i).

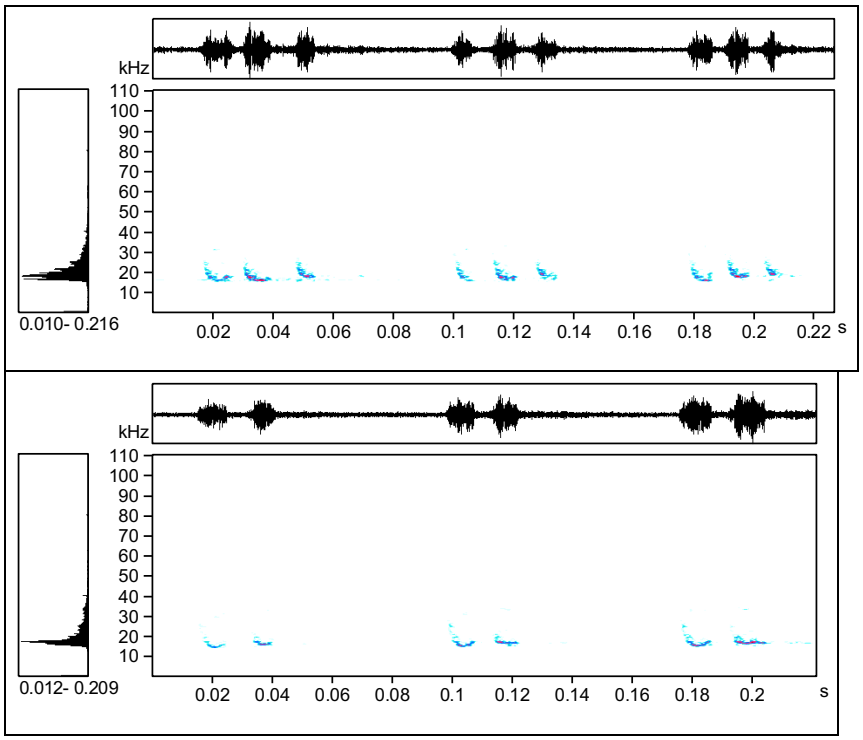


**Fig. 5.2.1.8 i:** Low-frequency social calls of call type I from a Noctule (*N. noctula*) from inside tree cavity No. 4 at dawn before sunrise (Kaiserslautern Vogelwoog, 27 August 1999, 5:43 and 6:19)

**Tab. 5.2.1.8 i:** Statistical parameters of call type I from the Noctule (*N. noctula*)

| | Duration [ms] | $F_{max}$ [kHz] | $F_{end}$ [kHz] |
|---|---|---|---|
| Sample size | 126 | 126 | 126 |
| **Median** | **40,050** | **18,519** | **15,073** |
| Minimum | 20,300 | 14,643 | 11,628 |
| Maximum | 84,500 | 25,409 | 18,519 |
| Lower quartile | 31,900 | 16,365 | 14,212 |
| Upper quartile | 45,900 | 21,103 | 16,796 |
| **Average** | **40,202** | **18,905** | **15,354** |
| Standard deviation | 11,779 | 2,594 | 1,592 |

## J) Noctule (*N. noctula*): Call type J

As with call type I, calls of call type J were recorded almost exclusively at dusk or in the early morning hours. Sometimes, both types of calls were found within one recording sequence, occasionally also showing up fluent transitions. Call type J is characterised by low-frequency individual elements with a CF component and sometimes a steeply downward modulated start of the call (Fig. 5.2.1.8 j). The call duration is 11.6 - 61.8 ms (median: 22 ms) and both the peak frequency (median: 15.9 kHz) and the lowest frequency (median: 13.6 kHz) are in the audible frequency range. The silent periods between the calls are in median 45.6 ms (Tab. 5.2.1.8 j).

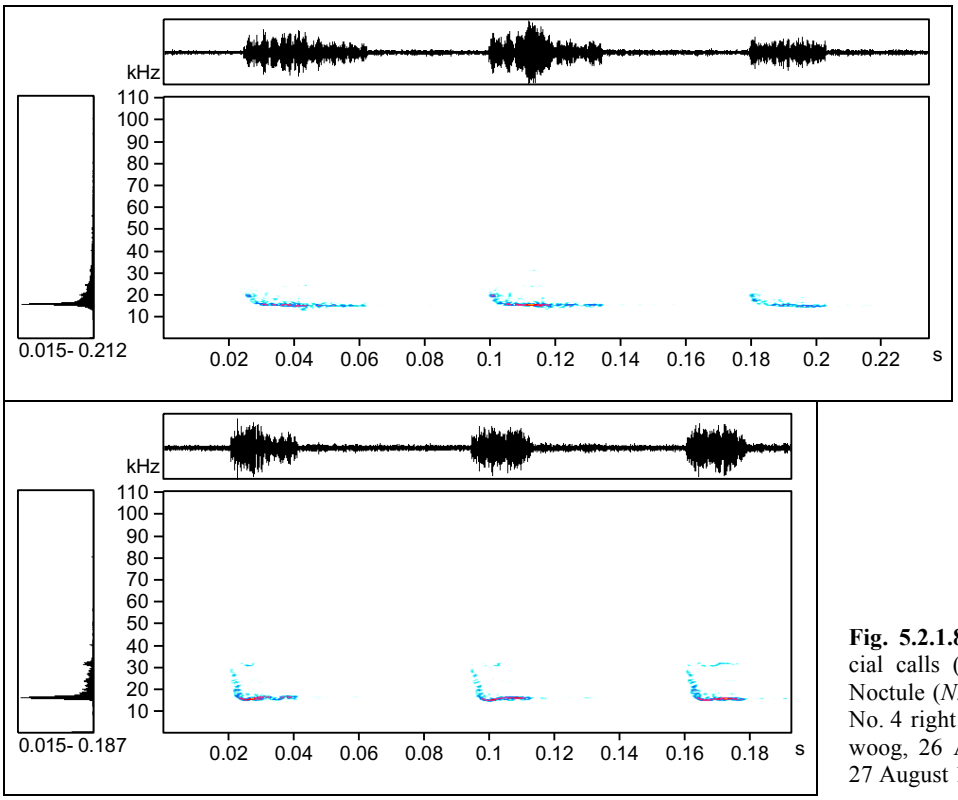


**Fig. 5.2.1.8 j:** Low-frequency social calls (Call type J) from the Noctule (*N. noctula*) at tree cavity No. 4 right before sunrise (Vogelwoog, 26 August 1999, 6:35 and 27 August 1999, 6:18)

**Tab. 5.2.1.8 j:** Statistical parameters of call type J from the Noctule (*N. noctula*)

| | Duration [ms] | $F_{max}$ [kHz] | $F_{end}$ [kHz] | Call pauses |
|---|---|---|---|---|
| Sample size | 70 | 70 | 70 | 92 |
| **Median** | **21,950** | **15,935** | **13,566** | **45,600** |
| Minimum | 11,600 | 12,059 | 9,475 | 33,100 |
| Maximum | 61,800 | 19,380 | 16,796 | 99,000 |
| Lower quartile | 18,300 | 15,073 | 12,489 | 39,050 |
| Upper quartile | 36,900 | 16,796 | 14,212 | 51,250 |
| **Average** | **27,524** | **15,793** | **13,400** | **47,643** |
| Standard deviation | 12,854 | 1,355 | 1,626 | 11,841 |

## K) Noctule (*N. noctula*): Call type K

Replayed in time-expansion, calls of the call type K remind of a "cawing roar" and are emitted in long call sequences. The detector recordings were made on the afternoon of the 26th of August 1999 when controlling tree roost No. 2 by means of a ladder system used for professional tree-climbing. In the course of the tree-hole inspection, the roost occupant left the tree cavity and entered the woodpecker hole of tree roost No. 4 where another Noctule was located. In the context of the recorded sequences, the calls of both animals found in tree roost No. 4 could be differentiated. Accordingly, the roost occupant emitted calls of the call types I and J while the "intruder" from tree No. 2 emitted the rhythmic "roar" of call type K. These calls are multi-harmonic CF pulses with a slightly upward modulation at the beginning and a light downward modulation at the end of the call (Fig. 5.2.1.8 k). The call duration is approximately 43 - 84 ms (median: 62.7 ms), the peak frequency is in the audible range with a median of 13.4 kHz and the lowest frequency is around 8.2 kHz (Tab. 5.2.1.8 k).

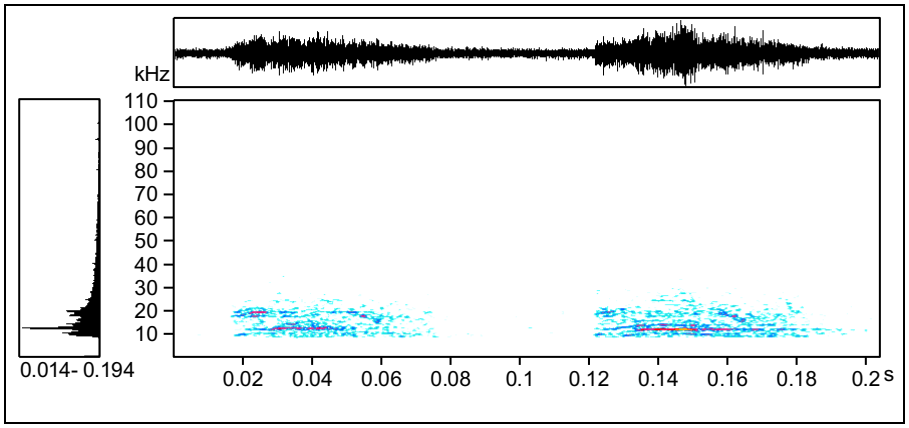


**Fig. 5.2.1.8 k:** Social calls of call type K from a Noctule (*N. noctula*) of tree roost No. 4 after the entry of a conspecific from tree roost No. 2 (Vogelwoog, 26 August 1999, 17:57)

**Tab. 5.2.1.8 k:** Statistical parameters of call type K from the Noctule (*N. noctula*)

| | Duration [ms] | $F_{max}$ [kHz] | $F_{end}$ [kHz] |
|---|---|---|---|
| Sample size | 41 | 41 | 41 |
| **Median** | **62,700** | **13,351** | **8,183** |
| Minimum | 42,700 | 9,475 | 7,321 |
| Maximum | 84,200 | 19,811 | 9,044 |
| Lower quartile | 50,800 | 11,628 | 8,183 |
| Upper quartile | 71,100 | 16,796 | 8,613 |
| **Average** | **61,602** | **14,002** | **8,235** |
| Standard deviation | 12,344 | 3,044 | 0,399 |

## 5.2.1.9 Lesser Noctule (*Nyctalus leisleri*, KUHL, 1817)

In the course of this work, social calls from the Lesser Noctule were recorded from inside roosts, as well as from flying individuals in foraging and mating areas. The roosts were located in tree cavities near Mölschbach (cf. Chapter 5.1.2 A) as well as in batboxes near Dannenfels (cf. chapter 3.3.2). Calls in foraging areas were recorded at Kaiserslautern Vogelwoog (KL 3), at a woodland edge near Stelzenberg (LA 1) and notably high in number over a parking area near the Betzenberg football stadium (S 3). Mating calls were recorded in two mating areas at Vogelwoog (KL 1) and Gelterswoog (S 1), as well as near Stelzenberg (LA 1), at Kaiserslautern wildlife park (KL 5) and in the central Palatinate Forest near Eschkopf (JO 2). In 1998, some calls were recorded while monitoring batboxes in Otterberg and Harthausen. A total of 14 call types were distinguished.

### A) Lesser Noctule (*N. leisleri*): Call type A

Social calls of call type A are emitted by Lesser Noctules during flight inside the mating territory or from a "song perch". They are slightly downward frequency-modulated (Fig. 5.2.1.9 a) and are emitted at very regular intervals with a repetition rate of approximately 1 Hz. In median, the measured frequencies cover a range between 18.9 kHz and 10.3 kHz (maximum-minimum values: 21.9 - 9.9 kHz). The peak frequency is 12.5 kHz and the median call duration is 30 ms (Tab. 5.2.1.9 a).

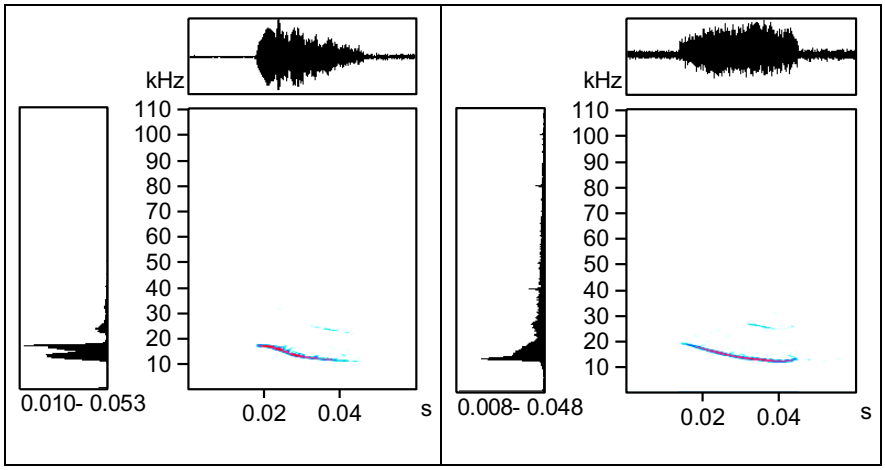


**Fig. 5.2.1.9 a:** Mating calls of type A from the Lesser Noctule (*N. leisleri*) (Left: Kaiserslautern-Hohenecken nearby Gelterswoog, 20 September 1999, 21:45; Right: Kaiserslautern wildlife park, 20 Juli 1998, 23:08)

**Tab. 5.2.1.9 a:** Statistical parameters of call type A from the Lesser Noctule (*N. leisleri*)

| | Duration [ms] | $F_{max}$ [kHz] | $F_{start}$ [kHz] | $F_{end}$ [kHz] | Call intervals [s] |
|---|---|---|---|---|---|
| Sample size | 51 | 51 | 51 | 51 | 246 |
| **Median** | **29,900** | **12,489** | **18,949** | **10,336** | **1,025** |
| Minimum | 21,200 | 12,059 | 17,657 | 9,905 | 0,689 |
| Maximum | 36,900 | 15,935 | 21,964 | 12,489 | 2,639 |
| Lower quartile | 27,900 | 12,489 | 18,519 | 9,905 | 0,905 |
| Upper quartile | 31,100 | 13,351 | 19,380 | 10,336 | 1,215 |
| **Average** | **29,208** | **12,920** | **18,941** | **10,454** | **1,119** |
| Standard deviation | 2,977 | 0,844 | 0,801 | 0,741 | 0,336 |

## B) Lesser Noctule (*N. leisleri*): Call type B

The highly characteristic calls of call type B were mostly recorded during aerial encounters of two foraging animals. They consist of two to six (median: four) downward frequency-modulated call elements. The initial element differs from the subsequent ones by its higher initial frequency (median $F_{start}$: 38.1 kHz) and its initially flat-falling frequency modulation, which becomes steeper towards the center of the call and ends in a nearly constant-frequency part. This results in a left-oblique S-shape (Fig. 5.2.1.9 b). In general, the $F_{max}$- und $F_{end}$-values of the individual pulses rise slightly towards the end of the call. The call duration varies, with the number of individual pulses ranging between 20.3 ms and 60.7 ms (Tab. 5.2.1.9 b). The call frequencies are largely outside the human auditory range.

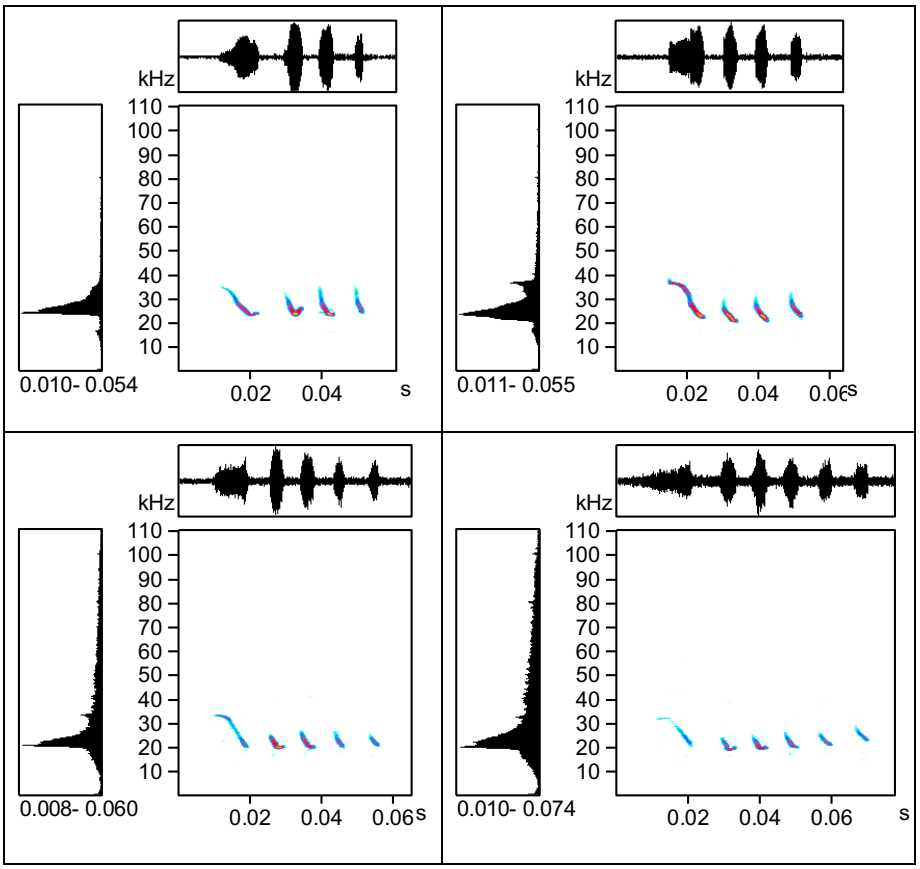


**Fig. 5.2.1.9 b:** Social calls of call type B from a flying Lesser Noctule (*N. leisleri*) in a foraging area (Left above: Kaiserslautern-Erzhütten nearby Vogelwoog (KL 3), 15 Mai 2000, 22:13; Right above: parking area Betzenberg football stadium (S 3), 8 Juni 2000, 0:08; Below: Calls with five or six elements, parking area Betzenberg football stadium (S 3), 28 Juli 2000, 23:53)

**Tab. 5.2.1.9 b:** Statistical parameters of call type B from the Lesser Noctule (*N. leisleri*)

| | Duration [ms] | $F_{max}$ [kHz] | $F_{start}$ [kHz] | $F_{end}$ [kHz] | Number elements |
|---|---|---|---|---|---|
| Sample size | 36 | 36 | 36 | 36 | 36 |
| **Median** | **38,000** | **22,395** | **38,114** | **20,241** | **4,000** |
| Minimum | 20,300 | 19,811 | 31,439 | 18,519 | 2,000 |
| Maximum | 60,700 | 24,117 | 43,066 | 22,395 | 6,000 |
| Lower quartile | 30,500 | 21,533 | 34,238 | 19,595 | 3,000 |
| Upper quartile | 41,350 | 23,256 | 39,190 | 20,457 | 4,000 |
| **Average** | **37,375** | **22,335** | **37,205** | **20,038** | **3,806** |
| Standard deviation | 7,682 | 1,179 | 3,172 | 0,888 | 0,749 |

| | $F_{max}$ 1 pulse [kHz] | $F_{max}$ 2 pulse [kHz] | $F_{max}$ 3 pulse [kHz] | $F_{max}$ 4 pulse [kHz] | $F_{end}$ 1 pulse [kHz] | $F_{end}$ 2 pulse [kHz] | $F_{end}$ 3 pulse [kHz] | $F_{end}$ 4 pulse [kHz] |
|---|---|---|---|---|---|---|---|---|
| Sample size | 36 | 36 | 35 | 25 | 36 | 36 | 35 | 25 |
| **Median** | **22,610** | **21,533** | **22,395** | **24,548** | **20,672** | **20,241** | **20,672** | **21,533** |
| Minimum | 20,672 | 19,811 | 19,811 | 20,672 | 18,519 | 18,519 | 18,949 | 19,380 |
| Maximum | 24,117 | 24,117 | 24,117 | 26,701 | 22,395 | 22,825 | 22,395 | 23,687 |
| Lower quartile | 21,964 | 21,103 | 21,964 | 23,256 | 20,241 | 19,595 | 19,811 | 20,241 |
| Upper quartile | 23,041 | 22,179 | 23,256 | 24,979 | 21,103 | 20,672 | 21,533 | 22,395 |
| **Average** | **22,466** | **21,701** | **22,284** | **23,928** | **20,672** | **20,205** | **20,512** | **21,326** |
| Standard deviation | 0,924 | 0,984 | 1,087 | 1,636 | 0,932 | 0,929 | 0,958 | 1,275 |

## C) Lesser Noctule (*N. leisleri*): Call type C

This call type is audible without a detector and sounds like a high and penetrating chirp. It was also emitted by foraging Lesser Noctules and consists of a series of short, low-frequency FM signals with at least one harmonic (Fig. 5.2.1.9 c). The median peak frequency is 18.7 kHz and the call duration ranges from 51.4 ms to 296.7 ms (median: 121.1 ms). The lowest frequency is generally below 10 kHz (median: 9 kHz) and the duration of the pulse intervals is 9.9 ms (Tab. 5.2.1.9 c).

**Tab. 5.2.1.9 c:** Statistical parameters of the call type C of the Lesser Noctule (*N. leisleri*)

| | Duration [ms] | $F_{max}$ [kHz] | $F_{start}$ [kHz] | $F_{end}$ [kHz] | Pulse intervals [ms] |
|---|---|---|---|---|---|
| Sample size | 12 | 12 | 12 | 12 | 98 |
| **Median** | **121,050** | **18,734** | **26,055** | **9,044** | **9,900** |
| Minimum | 51,400 | 10,767 | 21,964 | 8,613 | 5,500 |
| Maximum | 296,700 | 22,395 | 31,008 | 9,475 | 16,000 |
| Lower quartile | 85,050 | 15,719 | 23,902 | 8,613 | 9,300 |
| Upper quartile | 166,350 | 20,672 | 28,639 | 9,044 | 10,700 |
| **Average** | **132,275** | **17,980** | **26,306** | **8,936** | **10,281** |
| Standard deviation | 70,883 | 3,714 | 2,770 | 0,325 | 1,728 |

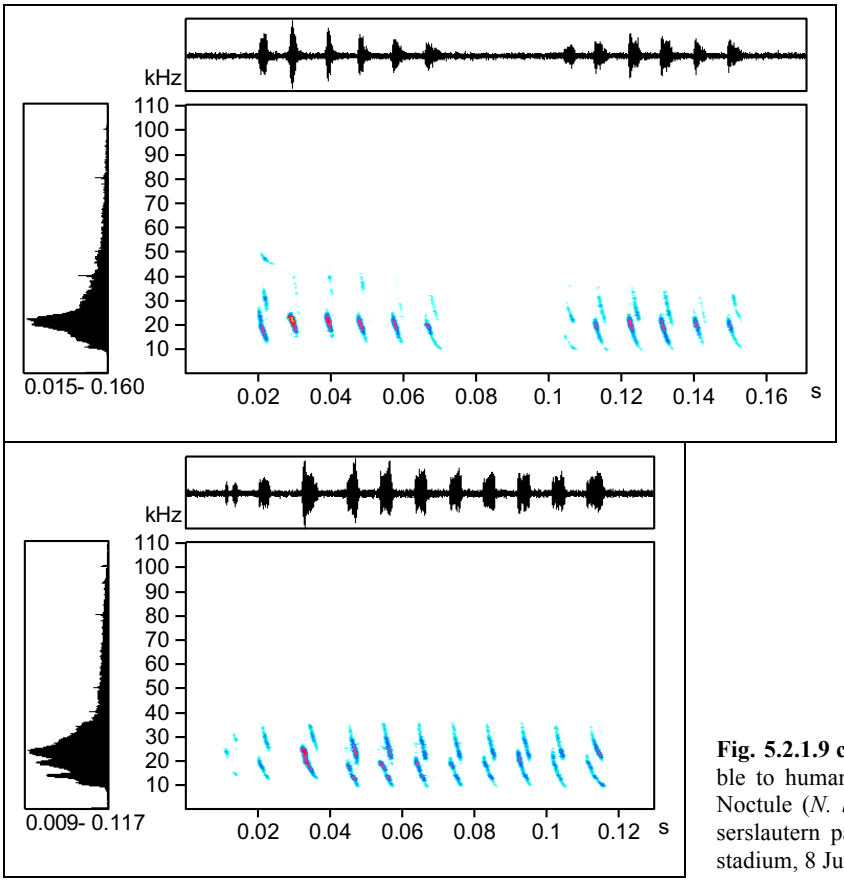


**Fig. 5.2.1.9 c:** Social calls (call type C) audible to humans, emitted from a flying Lesser Noctule (*N. leisleri*) in a foraging area (Kaiserslautern parking area Betzenberg football-stadium, 8 June 2000, 23:58 and 0:08)

## D) Lesser Noctule (*N. leisleri*): Call type D

The calls of this call type are also audible for humans. They were recorded among others while monitoring batboxes near Otterberg and near Harthausen. Once on the 28th of July 1999, the call was also registered at a tree roost near Mölschbach. Furthermore, it was detected from a maternity colony in a batbox near Dannenfels on the 1st of July 2000, before the females left the roost in the evening taking the flightless juveniles with them. In addition, a recording on the 5th of September 2000 took place in the same roost-site area, the calls being emitted from a batbox with about 15 juvenile Lesser Noctules already capable of flight and independent. Similar to call type C, these are series of FM pulses which, however, overlap in a narrower frequency range (median $F_{start}$: 18.9 kHz, $F_{end}$: 10.3 kHz). The calls consisting of four to nine individual pulses (median: five) have a duration between 27.3 ms and 56 ms (median: 38 ms) and median peak frequency of 13.8 kHz. The pulse intervals (8.3 ms) are clearly shorter than with call type C (Fig. and Tab. 5.2.1.9 d).

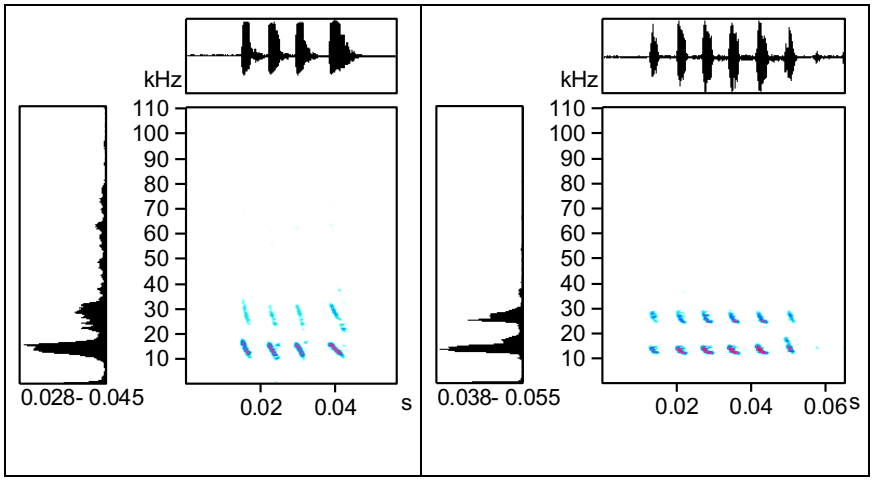


**Fig. 5.2.1.9 d:** Social calls (call type D) audible to humans, emitted by the Lesser Noctule (*N. leisleri*) (Left: during batbox monitoring near Otterberg, animal hand-held, 4 July 1998, 14:49; Right: tree cavity near Mölschbach, 28 July 1999, 22:02)

**Tab. 5.2.1.9 d:** Statistical parameters of call type D from the Lesser Noctule (*N. leisleri*)

| | Duration [ms] | $F_{max}$ [kHz] | $F_{start}$ [kHz] | $F_{end}$ [kHz] | Number elements | Pulse intervals [ms] |
|---|---|---|---|---|---|---|
| Sample size | 22 | 22 | 22 | 22 | 22 | 86 |
| **Median** | **38,000** | **13,781** | **18,949** | **10,336** | **5,000** | **8,300** |
| Minimum | 27,300 | 12,920 | 17,227 | 8,613 | 4,000 | 2,800 |
| Maximum | 56,000 | 15,504 | 24,548 | 11,628 | 9,000 | 12,400 |
| Lower quartile | 31,600 | 13,351 | 18,519 | 9,475 | 4,000 | 6,900 |
| Upper quartile | 40,900 | 14,212 | 19,380 | 10,767 | 5,000 | 9,200 |
| **Average** | **37,582** | **13,938** | **19,458** | **10,199** | **4,909** | **7,888** |
| Standard deviation | 6,822 | 0,658 | 1,970 | 0,895 | 1,192 | 2,128 |

## E) Lesser Noctule (*N. leisleri*): Call type E

Similar to the case of the Noctule, call type E from the Lesser Noctule is including social calls, which are "echolocation-like". Altogether, 321 single calls were analysed and divided into three subgroups. These are more or less steeply downward-modulated "bow-shaped" FM calls, which usually have a more or less constant frequency end section (Figs. 5.2.1.9 e1 - e3). Type E calls were emitted at roost-sites during periods of swarming activity with Lesser Noctules approaching, entering or leaving the roost.

### E.1) Call type E 1

This low-frequency variant of call type E was mainly emitted from inside the roost. The median peak frequency is 15.1 kHz and the call duration ranges between 26 ms and 72 ms (median: 45 ms). The calls cover a frequency range from 31.9 kHz to 13.4 kHz (maximum: 48.7 kHz, minimum: 8.6 kHz) and show at least one strong harmonic in the sonogram (Fig. and Tab. 5.2.1.9 e1).

### E.2) Call type E 2

Social calls of call type E 2 were emitted from Lesser Noctules swarming nearby the roost, as well as from individuals sitting inside. The recorded sequences from the 1st of July 2000, rendered at a

maternity colony with flightless juveniles, show very flatly modulated calls, mostly delivered in call series with more or less regular silent periods (median: 46.4 ms). On the other hand, the calls recorded around a tree roost near Mölschbach at the end of July 1999 and near Dannenfels at the beginning of September 2000 (Fig. 5.2.1.9 e2) had a broader frequency range and were predominantly emitted in flight at irregular intervals. The tree roosts were presumably used by a maternity colony, which was already in dispersal at the time of recording. Similarly, the batbox near Dannenfels, where these calls were registered in September, obviously contained a group of already weaned juveniles. The peak frequency of this call type is in median 17.7 kHz. It covers frequencies from 25.8 kHz down to 15.9 kHz (maximum-minimum values: 62 - 12.5 kHz). The call duration varies between 14.5 ms and almost 100 ms (Tab. 5.2.1.9 e2).

### E.3) Call type E 3

Detector recordings of this call type derive predominantly from swarming animals around tree roosts near Mölschbach. The calls are relatively short (median: 15.1 ms) and of high frequency (median $F_{max}$: 28 kHz). They cover a frequency range from 46.5 kHz down to 18.5 kHz (Fig. and Tab. 5.2.1.9 e3).

**Tab. 5.2.1.9 e1:** Statistical parameters of call type E 1 from the Lesser Noctule (*N. leisleri*)

| | Duration [ms] | $F_{max}$ [kHz] | $F_{start}$ [kHz] | $F_{end}$ [kHz] |
|---|---|---|---|---|
| Sample size | 37 | 37 | 37 | 37 |
| **Median** | **45,000** | **15,073** | **31,869** | **13,351** |
| Minimum | 26,100 | 13,351 | 18,088 | 8,613 |
| Maximum | 72,000 | 18,949 | 48,665 | 15,935 |
| Lower quartile | 39,500 | 14,643 | 24,548 | 12,920 |
| Upper quartile | 52,200 | 15,935 | 38,760 | 14,212 |
| **Average** | **45,176** | **15,318** | **32,288** | **13,257** |
| Standard deviation | 10,702 | 1,278 | 9,593 | 1,447 |

**Tab. 5.2.1.9 e2:** Statistical parameters of call type E 2 from the Lesser Noctule (*N. leisleri*)

| | Duration [ms] | $F_{max}$ [kHz] | $F_{start}$ [kHz] | $F_{end}$ [kHz] | Call pauses [ms] |
|---|---|---|---|---|---|
| Sample size | 269 | 269 | 269 | 269 | 173 |
| **Median** | **40,600** | **17,657** | **25,840** | **15,935** | **46,400** |
| Minimum | 14,500 | 15,504 | 21,103 | 12,489 | 26,400 |
| Maximum | 96,700 | 27,993 | 62,016 | 22,395 | 107,400 |
| Lower quartile | 34,000 | 17,227 | 24,117 | 14,643 | 38,000 |
| Upper quartile | 48,800 | 20,241 | 36,176 | 18,088 | 58,900 |
| **Average** | **41,400** | **18,863** | **30,081** | **16,445** | **49,303** |
| Standard deviation | 11,878 | 2,270 | 7,985 | 2,188 | 14,426 |

**Tab. 5.2.1.9 e3:** Statistical parameters of call type E 3 from the Lesser Noctule (*N. leisleri*)

| | Duration [ms] | $F_{max}$ [kHz] | $F_{start}$ [kHz] | $F_{end}$ [kHz] |
|---|---|---|---|---|
| Sample size | 15 | 15 | 15 | 15 |
| **Median** | **15,100** | **27,993** | **46,512** | **18,519** |
| Minimum | 6,400 | 24,548 | 36,176 | 14,212 |
| Maximum | 25,300 | 40,052 | 48,234 | 23,687 |
| Lower quartile | 8,700 | 27,132 | 41,774 | 16,796 |
| Upper quartile | 20,000 | 30,577 | 47,373 | 21,103 |
| **Average** | **14,853** | **29,142** | **44,387** | **18,863** |
| Standard deviation | 5,893 | 3,963 | 3,656 | 2,967 |

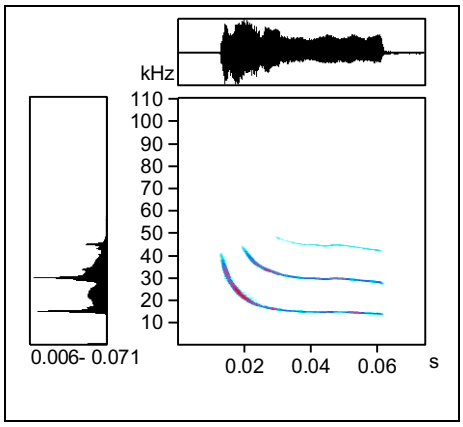


**Fig. 5.2.1.9 e1:** Low frequency "bow-shaped" social call of call type E 1 from the Lesser Noctule (*N. leisleri*) at the roost-site (tree cavity near Mölschbach, 30 Juli 1999, 5:14)

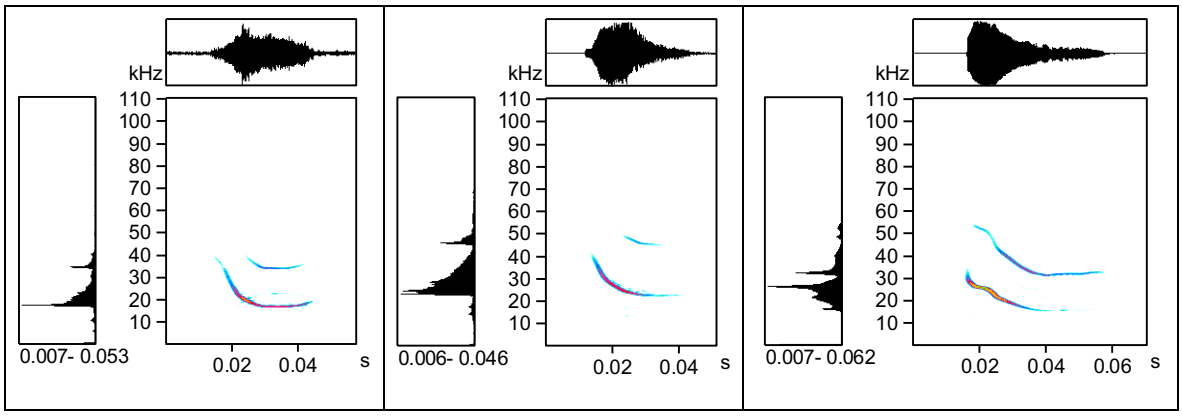


**Fig. 5.2.1.9 e2:** "Bow-shaped" social call of call type E 2 from the Lesser Noctule (*N. leisleri*) while swarming at the roost (Left: tree cavity near Mölschbach, 28 July 1999, 22:08; Center: batbox near Dannenfels, 5 September 2000, 22:10; Right: tree cavity near Mölschbach, 30 July 1999, 5:32)

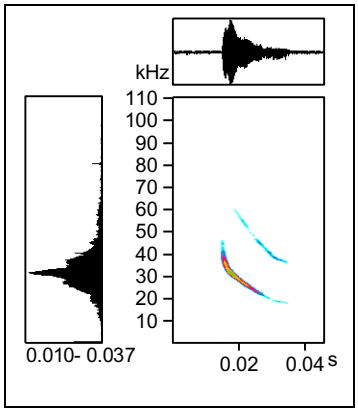


**Fig. 5.2.1.9 e3:** "Bow-shaped" social call of call type E 3 from the Lesser Noctule (*N. leisleri*) while swarming at the roost (tree cavity near Mölschbach, 30 July 1999, 5:10)

## F) Lesser Noctule (*N. leisleri*): Call type F

The conspicuous "double calls" of this call type were emitted during intense swarming periods, mainly from animals sitting inside the roost. At the tree cavity in Mölschbach, they were registered at dawn right before sunrise. At the maternity colony with flightless juveniles near Dannenfels, these calls were emitted with adults swarming in front of the roost shortly before a violent thundershower. During or immediately after the storm, a roost-switch occurred, and juveniles were carried away by their mothers. In some sequences, the calls seemed to be emitted in flight. However, it remains unclear whether the vocalisations originated from the females or from the transported juveniles. The call frequencies of the double calls are similar to those of the call type E. The calls are frequency-modulated at the beginning and change to a steeply rising FM part after an elongated, constant-frequency center part, whereupon a first steep and then flattening downwards modulation follows at the end (Fig. 5.2.1.9 f). The call duration is approximately 55.4 ms (44.7 - 69.1 ms) and the median of the peak frequency is 20.7 kHz (Tab. 5.2.1.9 f).

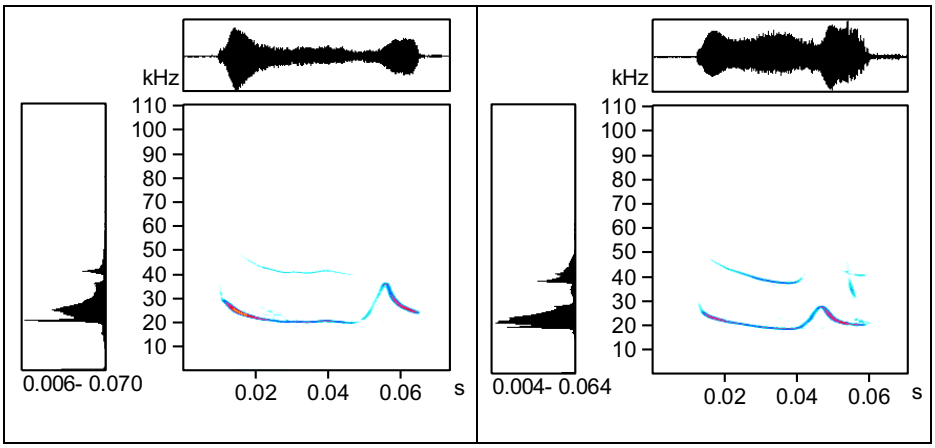


**Fig. 5.2.1.9 f:** "double-call" (call type F) from the Lesser Noctule (*N. leisleri*) while swarming at the roost (Tree cavity near Mölschbach, 30 July 1999, 5:53 and 5:23)

**Tab. 5.2.1.9 f:** Statistical parameters of call type F from the Lesser Noctule (*N. leisleri*)

| | Duration [ms] | $F_{max}$ [kHz] | $F_{start}$ [kHz] | $F_{end}$ [kHz] |
|---|---|---|---|---|
| Sample size | 23 | 23 | 23 | 23 |
| **Median** | **55,400** | **20,672** | **35,745** | **15,935** |
| Minimum | 44,700 | 14,643 | 27,132 | 12,920 |
| Maximum | 69,100 | 26,701 | 44,358 | 19,380 |
| Lower quartile | 50,200 | 17,657 | 32,300 | 14,643 |
| Upper quartile | 59,500 | 21,964 | 40,052 | 17,657 |
| **Average** | **55,561** | **20,129** | **35,764** | **16,159** |
| Standard deviation | 6,574 | 3,509 | 4,710 | 1,890 |

## G) Lesser Noctule (*N. leisleri*): Call type G

The "cawing" social calls of type G were mainly recorded on the 1st of July and 5th of September 2000 at Dannenfels. On the 1st of July, they were emitted at dusk before sunset and before the bats flew out of the roost. After the mothers had left the young animals in the batbox, the "cawing" went silent. The calls were registered again with the first adult females returning about two hours after sunset. On the 5th of September, they were also recorded in the period before sunset until the bats came flying out of the roost. In the sonogram, calls of type G result in an elongated, multi-harmonic noise (Fig. 5.2.1.9 g). The call duration is very alternating and the median of the peak frequency is 13.4 kHz. The lowest frequency is about 7.3 - 11.6 kHz (median: 8.6 kHz). In the cases of calls being emitted in series, the silent periods between two calls persist for about 50 ms (Tab. 5.2.1.9 g).

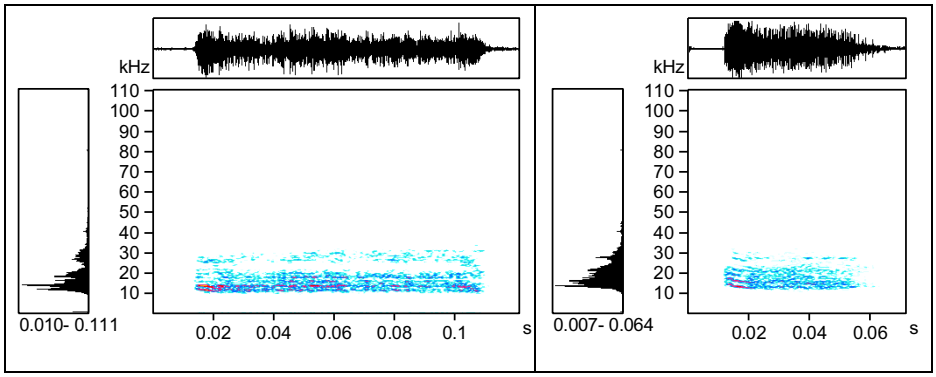


**Fig. 5.2.1.9 g:** "cawing" social calls of call type G from the Lesser Noctule (*N. leisleri*) from inside the roost (batbox near Dannenfels; Left: 1 Juli 2000, 21:21, ¼ hour before sunset; Right: 5 September 2000, 20:21, ¼ hour after sunset)

**Tab. 5.2.1.9 g:** Statistical parameters of call type G from the Lesser Noctule (*N. leisleri*)

| | Duration [ms] | $F_{max}$ [kHz] | $F_{end}$ [kHz] | Call pauses |
|---|---|---|---|---|
| Sample size | 135 | 135 | 135 | 13 |
| **Median** | **71,400** | **13,351** | **8,613** | **51,400** |
| Minimum | 10,700 | 10,336 | 7,321 | 13,100 |
| Maximum | 271,100 | 17,657 | 11,628 | 60,400 |
| Lower quartile | 40,300 | 12,489 | 8,183 | 48,200 |
| Upper quartile | 131,800 | 14,212 | 9,475 | 58,000 |
| **Average** | **90,873** | **13,456** | **8,996** | **49,946** |
| Standard deviation | 61,363 | 1,289 | 0,883 | 12,085 |

## H) Lesser Noctule (*N. leisleri*): Call type H

These sounds of up to nine individual elements, here referred to as call type H, have been emitted from the Dannenfels roost before the first bats flew out. The pulses have multi-harmonic noise bands with one or more harmonics (Fig. 5.2.1.9 h). The peak frequency lies between 11.6 kHz and 15.1 kHz (median: 13.4 kHz) and the call duration ranges between approximately 70 ms and

245 ms (median: 156.3 ms), depending on the number of elements involved. The median lowest frequency is 8.6 kHz, which is clearly in the audible frequency range of humans (Tab. 5.2.1.9 h).

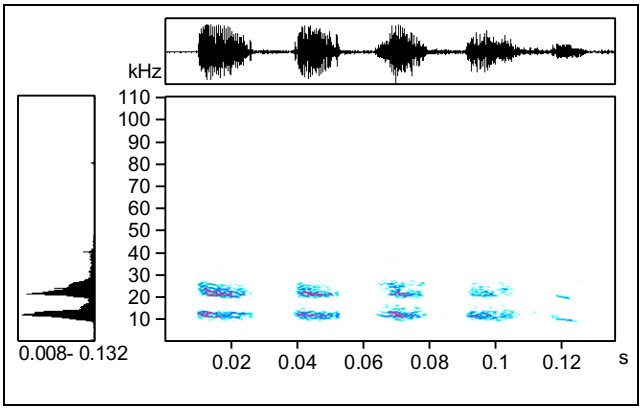


**Fig. 5.2.1.9 h:** Social calls of call type H from a Lesser Noctule (*N. leisleri*) before flying out of the roost (bat-box near Dannenfels, 5 September 2000, 20:14)

**Tab. 5.2.1.9 h:** Statistical parameters of call type H from the Lesser Noctule (*N. leisleri*)

| | Duration [ms] | $F_{max}$ [kHz] | $F_{end}$ [kHz] |
|---|---|---|---|
| Sample size | 16 | 16 | 16 |
| **Median** | **156,300** | **13,351** | **8,613** |
| Minimum | 69,700 | 11,628 | 7,752 |
| Maximum | 243,500 | 15,073 | 10,336 |
| Lower quartile | 115,950 | 12,489 | 8,398 |
| Upper quartile | 196,250 | 14,643 | 9,259 |
| **Average** | **156,163** | **13,512** | **8,829** |
| Standard deviation | 51,404 | 1,186 | 0,648 |

## I) Lesser Noctule (*N. leisleri*): Call type I

The social calls of call type I were emitted from inside the roosts before the beginning of flying out. The call elements (up to eight; median: three) are flattened to steep downward-modulated FM pulses with one or several hamonics (Fig. 5.2.1.9 i). The silent periods between the single pulses are 12.8 ms in median and the call duration of the entire call is between 28 ms and 219 ms (median: 59.3 ms). The call frequencies are largely in the human auditory range (Tab. 5.2.1.9 i).

Tab. 5.2.1.9 i: Statistical parameters of call type I from the Lesser Noctule (*N. leisleri*)

| | Duration [ms] | $F_{max}$ [kHz] | $F_{start}$ [kHz] | $F_{end}$ [kHz] | Number elements | Pulse intervals [ms] |
|---|---|---|---|---|---|---|
| Sample size | 52 | 54 | 49 | 54 | 54 | 129 |
| **Median** | **59,350** | **13,781** | **21,964** | **9,475** | **3,000** | **12,800** |
| Minimum | 28,200 | 10,767 | 14,643 | 8,183 | 2,000 | 2,900 |
| Maximum | 218,600 | 21,533 | 37,037 | 12,059 | 8,000 | 25,500 |
| Lower quartile | 45,450 | 13,351 | 18,519 | 8,613 | 3,000 | 9,300 |
| Upper quartile | 87,100 | 15,504 | 25,840 | 10,336 | 4,000 | 16,300 |
| **Average** | **73,415** | **14,244** | **23,098** | **9,642** | **3,481** | **12,822** |
| Standard deviation | 40,390 | 1,800 | 5,627 | 1,086 | 1,463 | 4,956 |

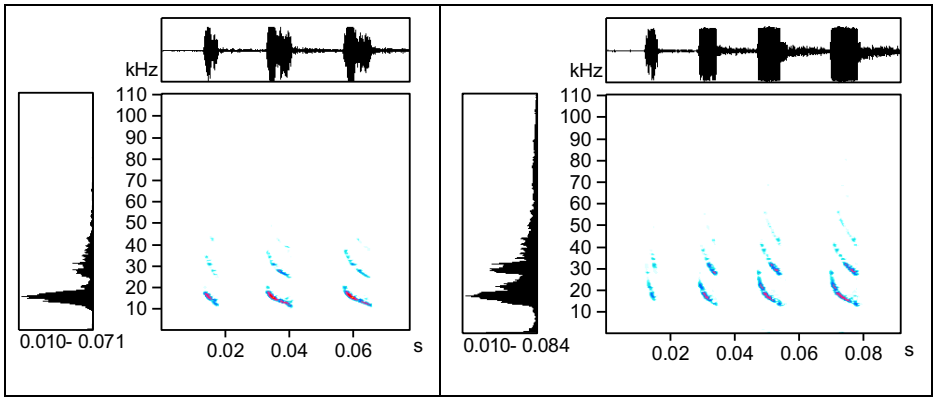


**Fig. 5.2.1.9 i:** Social calls of call type I from the Lesser Noctule (*N. leisleri*) from inside a roost before the flying out period (batbox near Dannenfels, 1 July 2000, 21:33 and 21:44)

## J) Lesser Noctule (*N. leisleri*): Call type J

Social calls of call type J were recorded before flying out of the roost, and in some cases even more than one hour before sunset. Immediately after the first animal had left the roost, no more calls were emitted. Calls of type J consist of two to six (median: five) steep FM pulses with a duration of 20 - 83 ms (median: 42.7 ms). Large parts of the frequency range are audible to humans (median $F_{max}$: 16.4 kHz, $F_{end}$: 10.8 kHz). The pulse intervals of the "trill-like" calls are in median 6.1 ms (Fig. and Tab. 5.2.1.9 j).

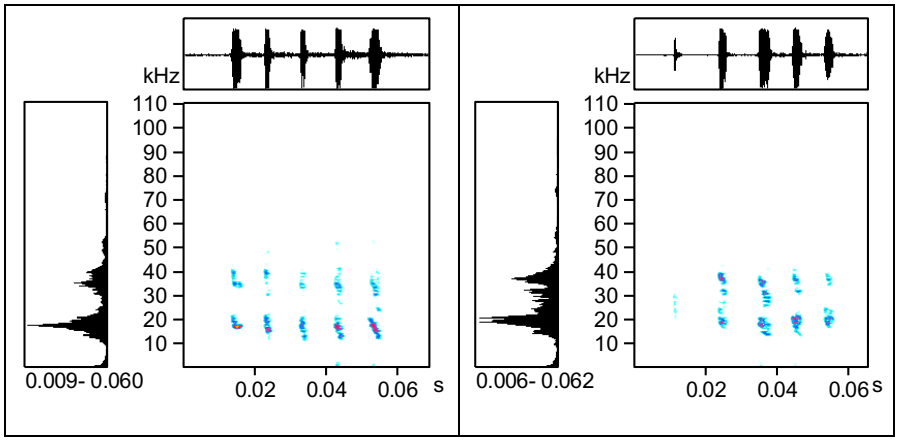


**Fig. 5.2.1.9 j:** "Trill-like" social calls (Call type J) from the Lesser Noctule (*N. leisleri*), emitted before flying out of the roost (batbox near Dannenfels, 1 July 2000, 21:31 and 5 September 2000, 20:21)

**Tab. 5.2.1.9 j:** Statistical parameters of call type J from the Lesser Noctule (*N. leisleri*)

| | Duration [ms] | $F_{max}$ [kHz] | $F_{start}$ [kHz] | $F_{end}$ [kHz] | Number elements | Pulse intervals [ms] |
|---|---|---|---|---|---|---|
| Sample size | 25 | 25 | 25 | 25 | 25 | 84 |
| **Median** | **42,700** | **16,365** | **26,701** | **10,767** | **5,000** | **6,100** |
| Minimum | 20,300 | 12,059 | 20,672 | 8,613 | 2,000 | 3,200 |
| Maximum | 82,700 | 21,533 | 41,344 | 13,351 | 6,000 | 16,800 |
| Lower quartile | 35,100 | 15,073 | 24,548 | 10,336 | 3,000 | 5,200 |
| Upper quartile | 46,700 | 18,088 | 30,147 | 11,628 | 5,000 | 7,500 |
| **Average** | **42,660** | **16,641** | **27,769** | **10,973** | **4,320** | **6,548** |
| Standard deviation | 13,208 | 2,455 | 4,380 | 1,147 | 1,108 | 2,153 |

## K) Lesser Noctule (*N. leisleri*): Call type K

Call type K was exclusively emitted before dawn from inside batboxes near Dannenfels. It was recorded as series of single or double calls with downwards frequency-modulated elements showing one or more harmonics (Fig. 5.2.1.9 k). The median of the peak frequency is 12.9 kHz. Frequencies between 19.4 kHz and 9.5 kHz are covered (maximum values: 31.9 - 8.2 kHz). The call duration varies between 6.7 ms and 61.2 ms, depending on whether it is a single or double call (Tab. 5.2.1.9 k).

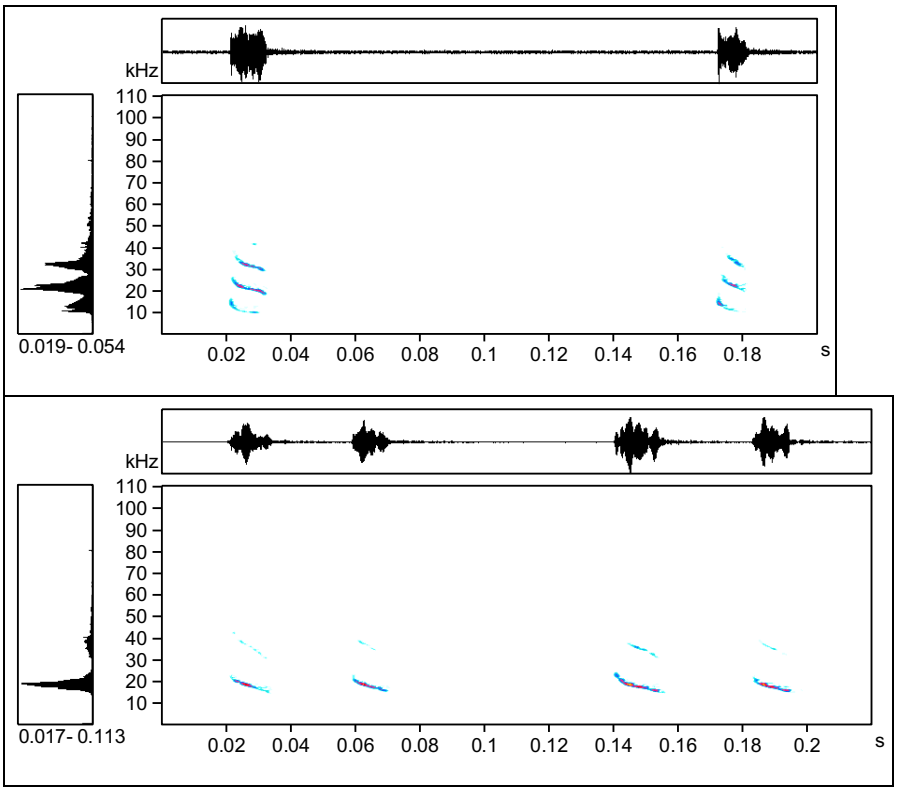


**Fig. 5.2.1.9 k:** Social calls of call type K from the Lesser Noctule (*N. leisleri*), emitted from inside the roost before sunset (batbox near Dannenfels, 1 July 2000; Above: single calls, 20:58; Below: double calls, 20:35, more than one hour before sunset)

## L) Lesser Noctule (*N. leisleri*): Call type L

This call type was recorded on the evening of the 1st of July 2000 and in the early morning of the 2nd of July 2000 from an abandoned flightless juvenile hanging in a neighbouring bat box outside the colony. After the females from the nearby maternity colony began to fly out, the juvenile emitted these loud calls, which were audible without a detector, almost continuously throughout the night in very regular call series (Fig. 5.2.1.9 ℓ2). After an explosive start of the call with a short, steeply downward modulated part, the sonogram shows an almost constant-frequency modulation with several harmonics (Fig. 5.2.1.9 ℓ1).

**Tab. 5.2.1.9 k:** Statistical parameters of call type L from the Lesser Noctule (*N. leisleri*)

| | Duration [ms] | $F_{max}$ [kHz] | $F_{start}$ [kHz] | $F_{end}$ [kHz] |
|---|---|---|---|---|
| Sample size | 49 | 49 | 49 | 49 |
| **Median** | **34,800** | **12,920** | **19,380** | **9,475** |
| Minimum | 6,700 | 10,336 | 12,920 | 8,183 |
| Maximum | 61,200 | 18,949 | 31,869 | 13,351 |
| Lower quartile | 15,400 | 12,059 | 17,227 | 8,613 |
| Upper quartile | 43,200 | 15,073 | 21,533 | 10,767 |
| **Average** | **32,227** | **13,781** | **20,355** | **10,046** |
| Standard deviation | 16,891 | 2,215 | 4,613 | 1,519 |

**Single call**

| | Duration [ms] | $F_{max}$ [kHz] | $F_{start}$ [kHz] | $F_{end}$ [kHz] |
|---|---|---|---|---|
| Sample size | 31 | 31 | 31 | 31 |
| **Median** | **17,100** | **12,489** | **18,088** | **9,475** |
| Minimum | 6,700 | 10,336 | 12,920 | 8,183 |
| Maximum | 48,200 | 16,796 | 31,869 | 12,920 |
| Lower quartile | 13,100 | 12,059 | 16,796 | 9,044 |
| Upper quartile | 38,000 | 13,781 | 21,103 | 10,336 |
| **Average** | **27,689** | **13,849** | **21,160** | **10,282** |
| Standard deviation | 12,765 | 1,774 | 4,814 | 1,255 |

**Double call**

| | Duration [ms] | $F_{max}$ [kHz] | $F_{start}$ [kHz] | $F_{end}$ [kHz] | Pulse intervals [ms] | Call pauses [ms] |
|---|---|---|---|---|---|---|
| Sample size | 18 | 18 | 18 | 18 | 18 | 8 |
| **Median** | **51,100** | **15,073** | **20,457** | **9,905** | **14,200** | **98,700** |
| Minimum | 32,500 | 10,767 | 15,935 | 8,613 | 10,400 | 69,100 |
| Maximum | 61,200 | 18,949 | 30,147 | 13,351 | 29,900 | 159,300 |
| Lower quartile | 38,300 | 12,489 | 19,380 | 8,613 | 11,000 | 77,500 |
| Upper quartile | 55,700 | 16,796 | 24,117 | 12,059 | 21,500 | 117,700 |
| **Average** | **52,979** | **16,065** | **23,912** | **11,360** | **18,924** | **127,361** |
| Standard deviation | 9,799 | 2,571 | 3,820 | 1,866 | 5,791 | 30,306 |

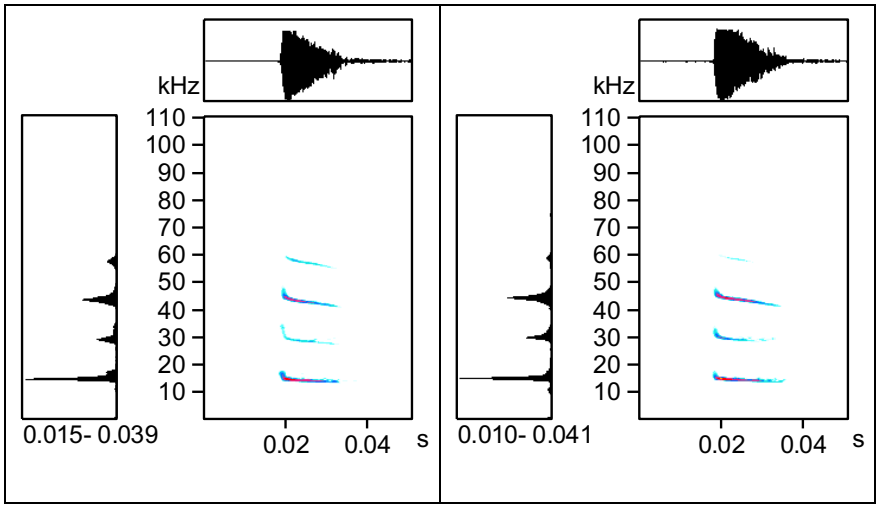


**Fig. 5.2.1.9 f1:** Social calls (Call type L) from an abandoned juvenile of the Lesser Noctule (*N. leisleri*) (batbox near Dannenfels, 1 July 2000, 23:11)

The median duration of single calls is 15.4 ms with a peak frequency of 12.1 - 15.5 kHz (median: 13.8 kHz). They cover a frequency range from 17.7 kHz to 12.1 kHz (maximum values: 21.1 - 10.3 kHz) and are thus almost completely within the human audible range. The silent periods between the calls are about 175 ms, which corresponds to a repetition rate of 5.7 Hz (Tab. 5.2.1.9 ℓ and Fig. 5.2.1.9 ℓ2).

**Tab. 5.2.1.9 ℓ:** Statistical parameters of call type L from the Lesser Noctule (*N. leisleri*)

| | Duration [ms] | $F_{max}$ [kHz] | $F_{start}$ [kHz] | $F_{end}$ [kHz] | Call pauses [ms] |
|---|---|---|---|---|---|
| Sample size | 324 | 324 | 324 | 324 | 322 |
| **Median** | **15,400** | **13,781** | **17,657** | **12,059** | **174,600** |
| Minimum | 9,000 | 12,059 | 15,504 | 10,336 | 87,900 |
| Maximum | 35,700 | 15,504 | 21,103 | 13,781 | 417,400 |
| Lower quartile | 13,100 | 13,351 | 17,227 | 11,628 | 158,800 |
| Upper quartile | 18,300 | 14,212 | 18,519 | 12,489 | 219,700 |
| **Average** | **16,373** | **13,817** | **17,875** | **12,028** | **188,391** |
| Standard deviation | 4,688 | 0,669 | 1,173 | 0,717 | 42,754 |

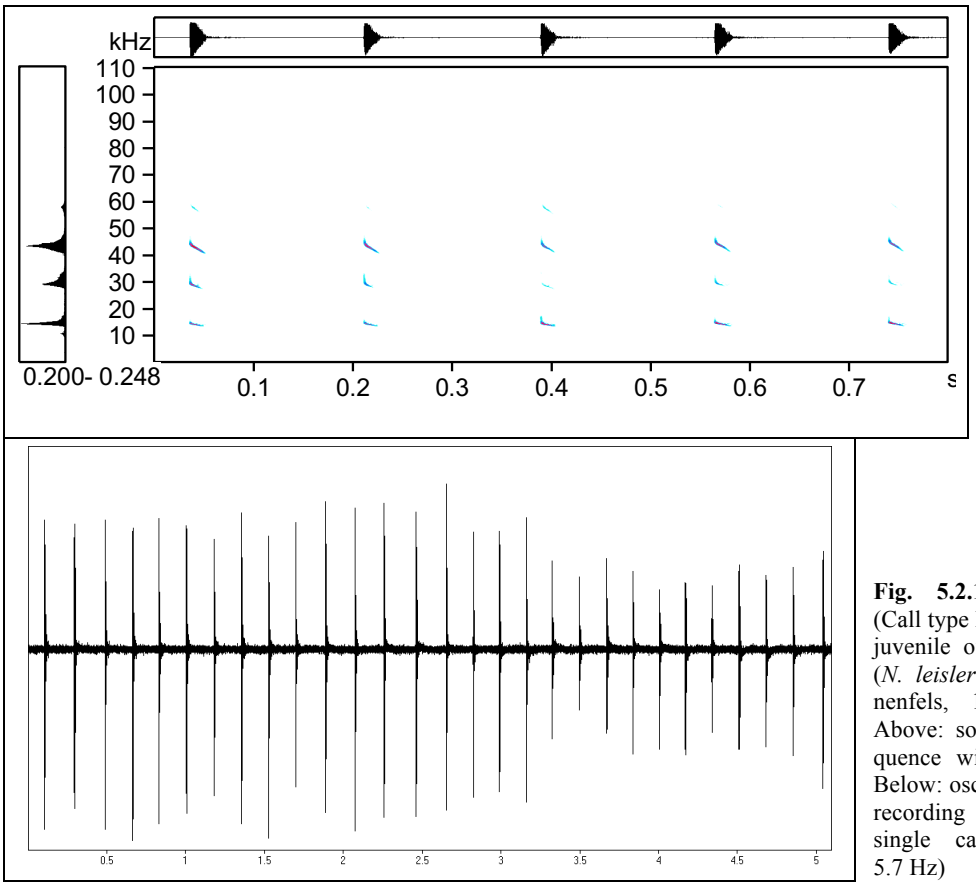


**Fig. 5.2.1.9 ℓ2:** Social calls (Call type L) from an abandoned juvenile of the Lesser Noctule (*N. leisleri*) (batbox near Dannenfels, 1 July 2000, 23:11; Above: sonogram of a call sequence with five single calls; Below: oscillogram of a 5 s long recording sequence with 29 single calls, repetition rate: 5.7 Hz)

## M) Lesser Noctule (*N. leisleri*): Call type M

The "trill-like" calls of call type M were emitted on the 1st of July 2000 before sunset and before the adult females of the maternity colony began to fly out. They resemble those of call type C, which were, on the contrary, emitted from flying animals in the foraging area. The trill consists of a series of short, low-frequency FM signals. Usually, one or more harmonics occur in the sonogram (Fig. 5.2.1.9 m). Peak frequency (median $F_{max}$: 14.6 kHz) and lowest frequency (median $F_{end}$: 10.3 kHz) are clearly in the audible frequency range. The pulse intervals have a relatively constant length of approximately 9 ms and the call duration (median: 108.6 ms) varies greatly depending on the number of FM pulses (Tab. 5.2.1.9 m).

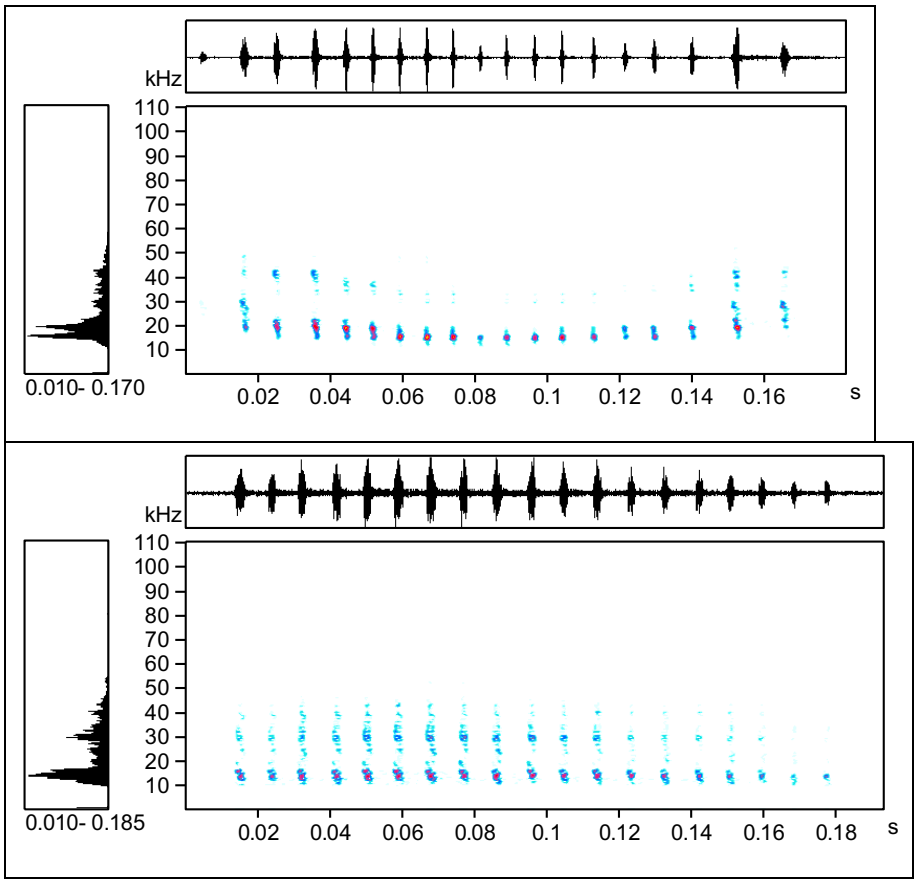


**Fig. 5.2.1.9 m:** "Trill-like" social calls (call type M) from the Lesser Noctule (*N. leisleri*) at a maternity colony before sunset (batbox near Dannenfels, 1 July 2000, 20:53, 21:25)

**Tab. 5.2.1.9 m:** Statistical parameters of call type M from the Lesser Noctule (*N. leisleri*)

| | Duration [ms] | $F_{max}$ [kHz] | $F_{start}$ [kHz] | $F_{end}$ [kHz] | Pulse intervals [ms] |
|---|---|---|---|---|---|
| Sample size | 5 | 5 | 5 | 5 | 64 |
| **Median** | **108,600** | **14,643** | **21,533** | **10,336** | **9,000** |
| Minimum | 72,000 | 13,351 | 19,811 | 9,475 | 7,300 |
| Maximum | 176,800 | 15,935 | 31,008 | 11,197 | 13,600 |
| Lower quartile | 78,700 | 13,351 | 20,672 | 9,905 | 8,400 |
| Upper quartile | 166,600 | 15,935 | 25,409 | 10,336 | 9,900 |
| **Average** | **120,540** | **14,643** | **23,687** | **10,250** | **9,300** |
| Standard deviation | 48,826 | 1,292 | 4,618 | 0,639 | 1,381 |

## N) Lesser Noctule (*N. leisleri*): Call type N

Social calls of this call type were recorded on the evening of the 1st of July 2000 at a maternity colony directly before the first bats left the roost as well as on the 5th of September 2000 from inside a batbox occupied with already weaned young bats. The call consists of a series of short FM pulses (Fig. 5.2.1.9 n). The call duration is 48 - 200 ms (median: 111.5 ms) and the median of the peak frequency is 31.2 kHz. With a length of about 16 ms, the call intervals are relatively long. The FM pulses cover frequencies between 46.9 kHz and 18.3 kHz (Tab. 5.2.1.9 n).

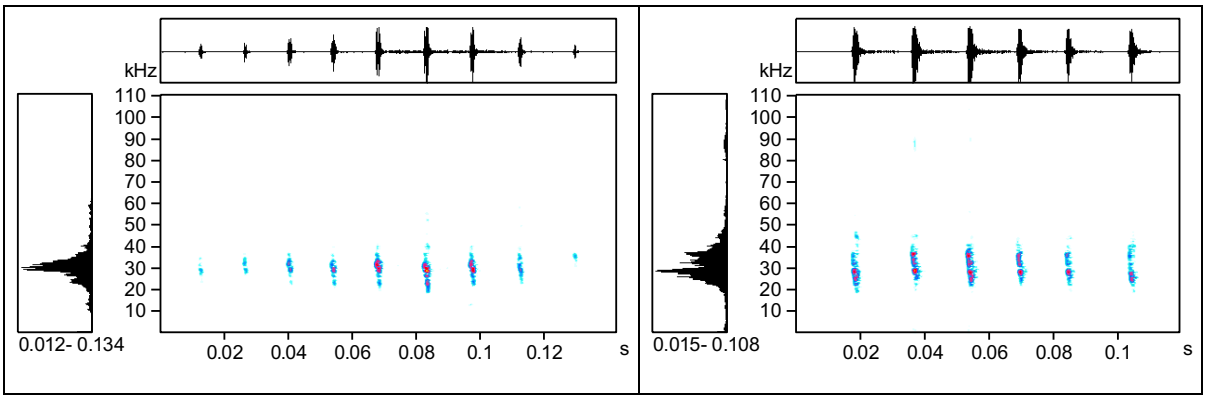


**Fig. 5.2.1.9 n:** "Trill-like" social calls (Call type N) from the Lesser Noctule (*N. leisleri*) shortly before the first bats flew out of the roost at dusk (batbox near Dannenfels, 1 July 2000, 21:40 and 20:01)

**Tab. 5.2.1.9 n:** Statistical parameters of call type N from the Lesser Noctule (*N. leisleri*)

| | Duration [ms] | $F_{max}$ [kHz] | $F_{start}$ [kHz] | $F_{end}$ [kHz] | Call intervals [ms] |
|---|---|---|---|---|---|
| Sample size | 18 | 18 | 18 | 18 | 121 |
| **Median** | **111,450** | **31,223** | **46,942** | **18,303** | **16,000** |
| Minimum | 47,900 | 24,979 | 43,066 | 15,935 | 9,300 |
| Maximum | 200,000 | 36,176 | 54,264 | 27,132 | 27,600 |
| Lower quartile | 100,100 | 28,855 | 45,220 | 16,796 | 14,200 |
| Upper quartile | 147,400 | 35,315 | 49,526 | 21,103 | 18,300 |
| **Average** | **118,644** | **31,438** | **47,684** | **19,380** | **16,216** |
| Standard deviation | 37,217 | 3,477 | 3,355 | 3,230 | 3,075 |

## 5.2.1.10 Serotine (*Eptesicus serotinus*, SCHREBER, 1774)

The here-analysed social calls from the Serotine originate from a maternity colony inside the attic of a church in Aspelt (Luxembourg). On the 30st of July 1998, detector recordings were made on a square in front of the building and inside the attic. According to SCHOBER & GRIMMBERGER (1998) the young bats were already weaned at this time and the dispersal of the maternity colony was imminent. After evaluation of the recorded call sequences, at least four call types were distinguished.

### A) Serotine (*E. serotinus*): Call type A

Similar to the Greater mouse-eared bat (*Myotis myotis*), a large part of these variable Serotine calls recorded inside the attic were summarised as call type A (see also chapter 5.2.1.7 A and 5.2.3.1). Figure 5.2.1.10 a shows an example of four calls, each of which was repeated several times while, and after the bats left the roost (n = 3 - 17). The statistical parameters of the measured call parameters are very inhomogeneous. The peak frequency of 77 individual calls analysed varies between 14.2 kHz and 23.7 kHz (median: 18.9 kHz). The calls cover frequencies between 23.7 kHz and 12.1 kHz (maximum-minimum values: 28.9 - 9.9 kHz). Sometimes, call series with silent periods of 97 ms are emitted (Tab. 5.2.1.10 a).

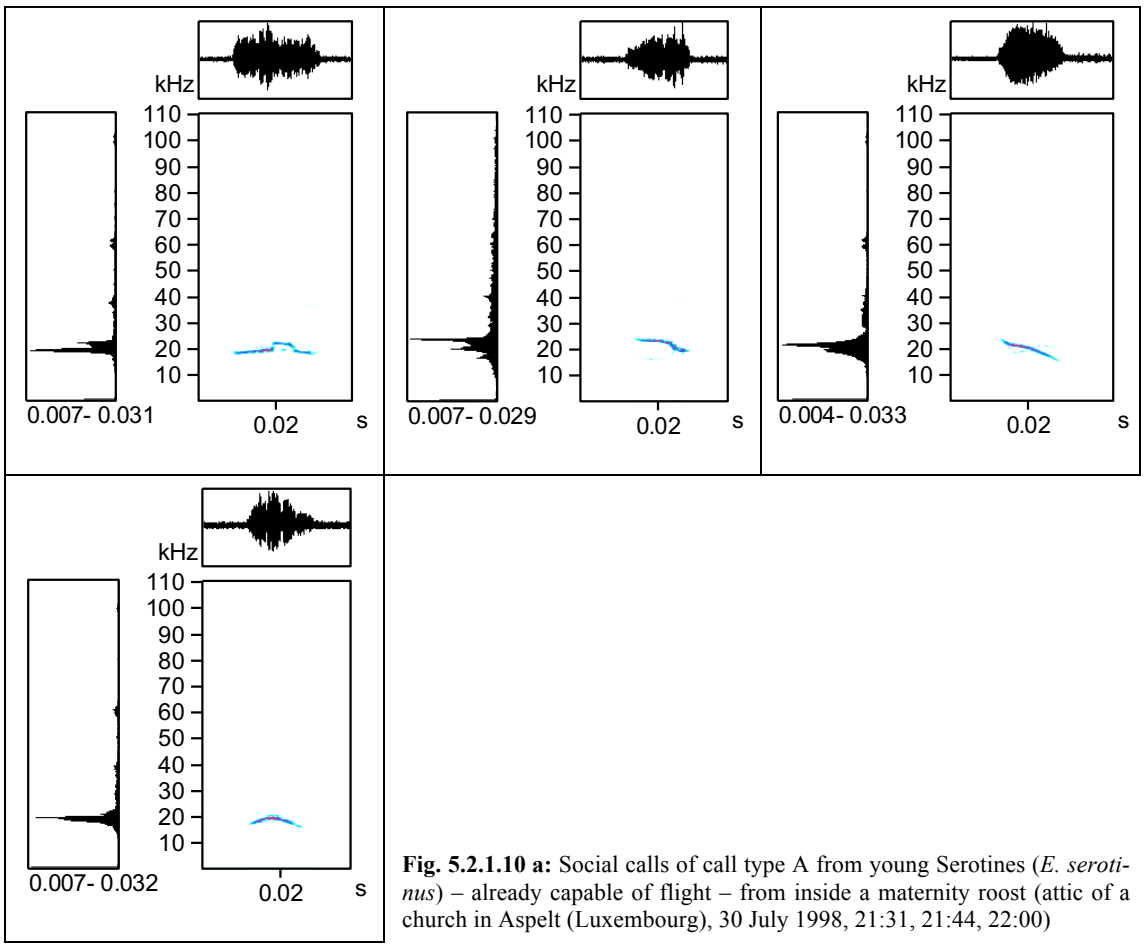


**Fig. 5.2.1.10 a:** Social calls of call type A from young Serotines (*E. serotinus*) – already capable of flight – from inside a maternity roost (attic of a church in Aspelt (Luxembourg), 30 July 1998, 21:31, 21:44, 22:00)

**Tab. 5.2.1.10 a:** Statistical parameters of call type A from the Serotine (*E. serotinus*)

| | Duration [ms] | $F_{max}$ [kHz] | $F_{start}$ [kHz] | $F_{end}$ [kHz] | Call pauses [ms] |
|---|---|---|---|---|---|
| Sample size | 77 | 77 | 77 | 77 | 17 |
| **Median** | **23,800** | **18,949** | **23,687** | **12,059** | **97,200** |
| Minimum | 16,000 | 14,212 | 17,227 | 9,905 | 72,000 |
| Maximum | 120,500 | 23,687 | 28,855 | 18,949 | 151,800 |
| Lower quartile | 19,700 | 18,519 | 21,103 | 11,197 | 82,400 |
| Upper quartile | 33,700 | 20,241 | 25,409 | 13,351 | 124,200 |
| **Average** | **33,339** | **19,296** | **23,412** | **12,685** | **104,300** |
| Standard deviation | 21,778 | 1,740 | 2,775 | 2,081 | 25,521 |

## B) Serotine (*E. serotinus*): Call type B

Merely two of these complexly structured social calls of the Serotine could be recorded. They were detected while the bats flew out in the evening and presumably came from the animals swarming in front of the roost. The sound sequences contain "V-shaped" elements with steep downwards and upwards modulated parts (Fig. 5.2.1.10 b). For the sake of completeness, the statistical parameters of the two measured calls are shown in Table 5.2.1.10 b. The peak frequency is right above 20 kHz, the highest frequency is about 45 kHz and the lowest frequency about 12 kHz.

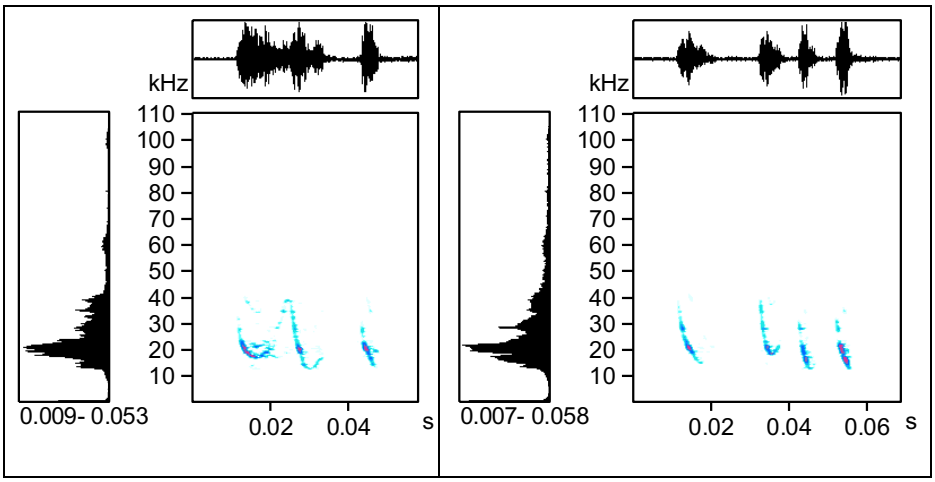


**Fig. 5.2.1.10 b:** Social calls of call type B from the Serotine (*E. serotinus*) during the evening emergence at a maternity roost (attic in Aspelt, Luxembourg, 30 July 1998, 21:36)

**Tab. 5.2.1.10 b:** Statistical parameters of call type B from the Serotine (*E. serotinus*)

| | Duration [ms] | $F_{max}$ [kHz] | $F_{start}$ [kHz] | $F_{end}$ [kHz] |
|---|---|---|---|---|
| Sample size | 2 | 2 | 2 | 2 |
| **Median** | **43,100** | **21,103** | **44,574** | **11,843** |
| Minimum | 39,500 | 20,672 | 41,344 | 11,628 |
| Maximum | 46,700 | 21,533 | 47,804 | 12,059 |
| Lower quartile | - | - | - | - |
| Upper quartile | - | - | - | - |
| **Average** | **43,100** | **21,103** | **44,574** | **11,843** |
| Standard deviation | 5,091 | 0,609 | 4,568 | 0,305 |

## C) Serotine (*E. serotinus*): Call type C

The sometimes very long "cawing" calls of type C were recorded about 45 minutes after the bats started leaving the roost and were emitted by the Serotines remaining inside (presumably young animals). The sonogram shows multi-harmonic noise bands, which in part have a rising frequency modulation at the beginning of the call and a downward-modulation at the end of the call (Fig. 5.2.1.10 c). The call duration varies between 75 ms and almost 300 ms (median: 198.4 ms). The median peak frequency is 21.1 kHz (Tab. 5.2.1.10 c).

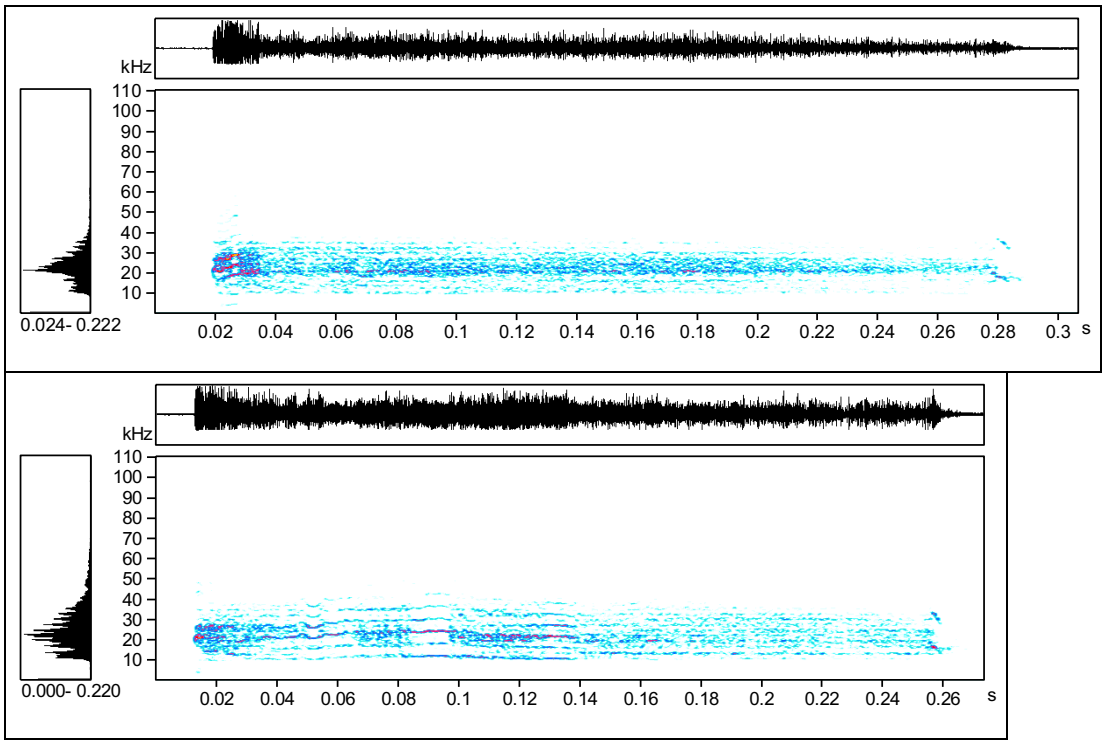


**Fig. 5.2.1.10 c:** "Cawing" social calls of call type C from the Serotine (*E. serotinus*) in a maternity roost after the bats started to fly out at dusk (attic of a church in Aspelt, Luxembourg, 30 July 1998, 22:19 and 22:23)

**Tab. 5.2.1.10 c:** Statistical parameters of call type C from the Serotine (*E. serotinus*)

| | Duration [ms] | $F_{max}$ [kHz] |
|---|---|---|
| Sample size | 18 | 18 |
| **Median** | **198,400** | **21,103** |
| Minimum | 74,600 | 12,059 |
| Maximum | 293,400 | 22,825 |
| Lower quartile | 126,300 | 18,088 |
| Upper quartile | 271,100 | 21,533 |
| **Average** | **196,583** | **19,643** |
| Standard deviation | 74,024 | 3,053 |

## D) Serotine (*E. serotinus*): Call type D

The "trill-like" calls of this call type were also recorded in front of the roost when the bats started to fly out. When recording, single bats had been observed swarming outside the roost. It was not possible to determine whether the calls were emitted by individuals in flight, or by individuals sitting at the roost entry. A trill consists of three to five short and steep FM pulses (Fig. 5.2.1.10 d). The statistical parameters are very similar to those of type C from the Lesser Noctule (*Nyctalus leisleri*). Call duration and pulse intervals are usually shorter (median call duration: 38.3 ms, median pulse intervals: 9 ms). The calls cover frequencies between 21.1 kHz and 10.3 kHz (maximum-minimum values: 44.8 - 8.6 kHz). The median peak frequency is 18.1 kHz (Tab. 5.2.1.10 d).

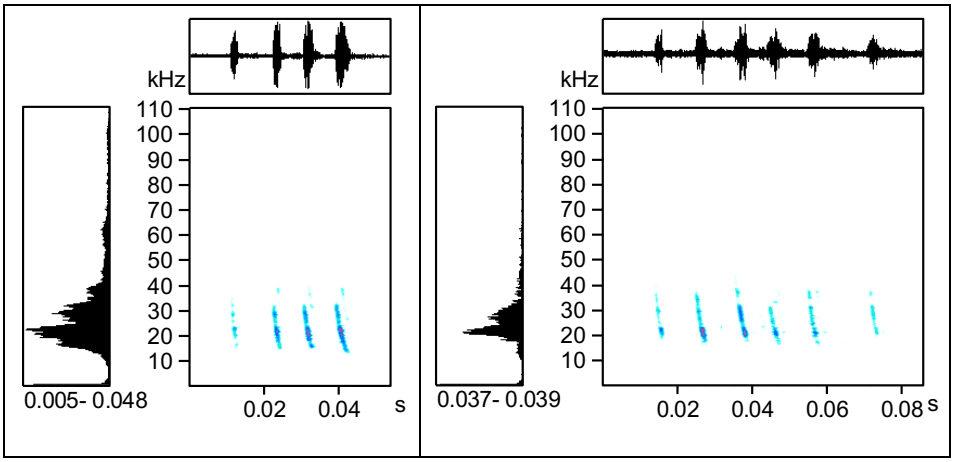


**Fig. 5.2.1.10 d:** "Trill-like" social calls (Call type D) from the Serotine (*E. serotinus*) during the evening fly-out period (attic of a church in Aspelt, Luxembourg, 30 July 1998, 21:36)

**Tab. 5.2.1.10 d:** Statistical parameters of call type D from the Serotine (*E. serotinus*)

| | Duration [ms] | $F_{max}$ [kHz] | $F_{start}$ [kHz] | $F_{end}$ [kHz] | Number elements | Pulse interval [ms] |
|---|---|---|---|---|---|---|
| Sample size | 9 | 9 | 9 | 9 | 9 | 31 |
| **Median** | **38,300** | **18,088** | **21,103** | **10,336** | **5,000** | **9,000** |
| Minimum | 24,100 | 13,351 | 17,657 | 8,613 | 3,000 | 7,800 |
| Maximum | 76,000 | 21,964 | 44,789 | 13,351 | 5,000 | 27,300 |
| Lower quartile | 33,700 | 18,088 | 20,241 | 9,905 | 4,000 | 8,400 |
| Upper quartile | 45,600 | 18,519 | 23,256 | 10,767 | 5,000 | 11,300 |
| **Average** | **44,078** | **18,040** | **24,931** | **10,623** | **4,444** | **11,042** |
| Standard deviation | 18,517 | 2,770 | 8,947 | 1,379 | 0,726 | 4,661 |

## 5.2.1.11 Northern bat (*Eptesicus nilssonii*, KEYSERLING & BLASIUS, 1839)

An injured specimen of the Northern bat (*E. nilssonii*) from Neuhof (TK 6612) was handed over to the author on the 19th of July 2001. The social calls recorded originate from this animal.

### A) Northern bat (*E. nilssonii*): Call type A

The injured and non-lactating female emitted very loud and clearly audible calls with a repetition rate of about 8 Hz. The variable calls appear as "bow-shaped" in the sonogram and show several harmonics (Fig. 5.2.1.11 a). Thus, they resemble the social calls of type E from the Lesser Noctule (*Nyctalus leisleri*, see chapter 5.2.1.9 E). They are up to 50 ms in length and sometimes range down to below 10 kHz. An exact call analysis with determination of the statistical parameters was not performed because of the small database.

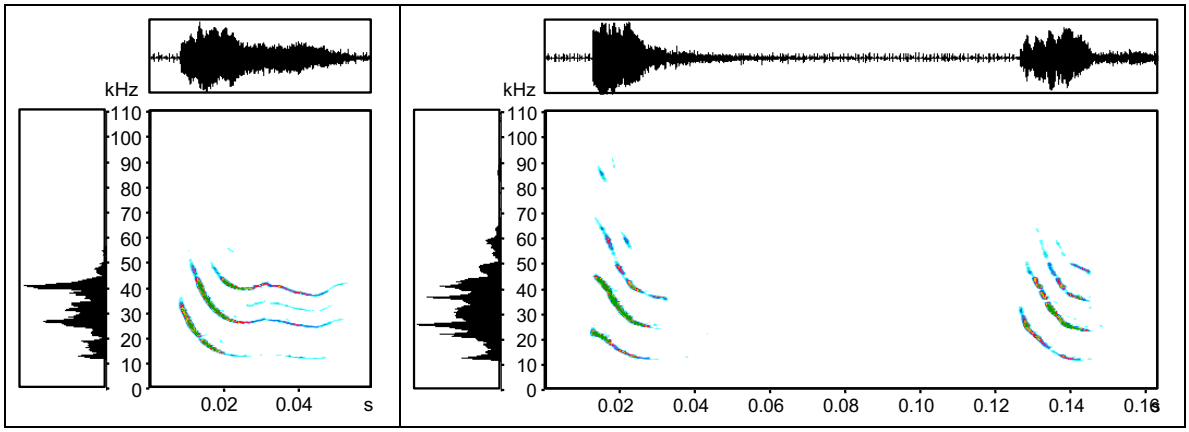


**Fig. 5.2.1.11 a:** "Bow-shaped" social calls of call type A from a hand-held Northern bat (*E. nilssonii*) (22. July 2001, 16:00)

# 5.2.1.12 Particoloured bat (*Vespertilio murinus*, LINNAEUS, 1758)

Social calls from *V. murinus* were recorded on the 31st of October 1999 and on the 16th of October 2000 at Betzenberg in Kaiserslautern. Most of the recordings were performed in front of a multi-storey building in "Rousseaustraße" No. 6, already described by WISSING (1996) as a hibernation-site of the Noctule. In addition, several individuals of the Particoloured bat were recorded performing songflight at nearby multi-storey buildings in "Kantstraße", "St.-Quentin-Ring" and "Malzstraße". Call activity started approximately two hours after sunset. An observation on the 4th of February 2001 suggests that a multi-storey building in "Malzstraße" may have been used for hibernation.

## A) Particoloured bat (*V. murinus*): Call type A

Figure 5.2.1.12 a1 shows a characteristic social call from the Particoloured bat. It consists of nine steeply downwards modulated FM pulses followed by a loud "L-shaped" element. The number of FM elements varies between five and eleven (median: seven). FM pulses and "L-element" are often connected by a "V-shaped" call part. The median of the regular pulse intervals is 10.2 ms, and the calls themselves have a maximum duration of more than 200 ms (median: 180 ms). The conspicuous "L-element", which is audible as a "zip"-sound, has a length of approximately 22.1 ms, its peak frequency is 12.9 kHz, the highest frequency is 36.6 kHz and the lowest frequency is 8.6 kHz (median values). The calls are emitted in persistent and very regular sequences with intervals of approximately 132 ms (n = 349), which corresponds to a repetition rate of 7.6 Hz (Tab. 5.2.1.12 a and Fig. 5.2.1.12 a2).

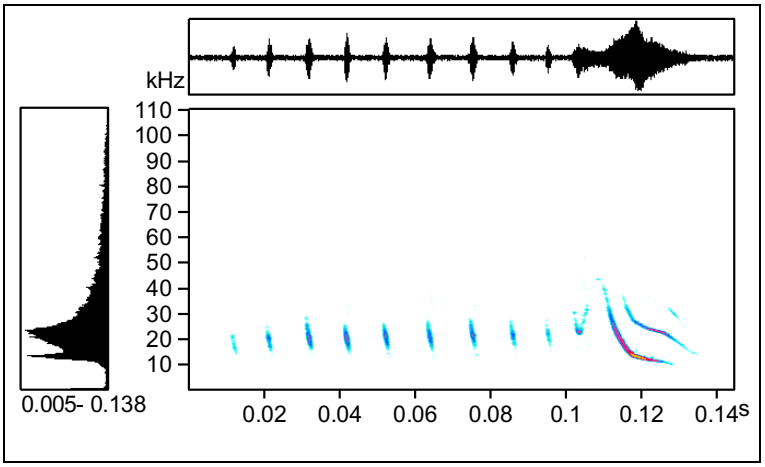


**Fig. 5.2.1.12 a1:** Social call of call type A from a Particoloured bat (*V. murinus*) in songflight (residential area with multi-storey buildings at Betzenberg in Kaiserslautern, 16 October 2000, 21:05)

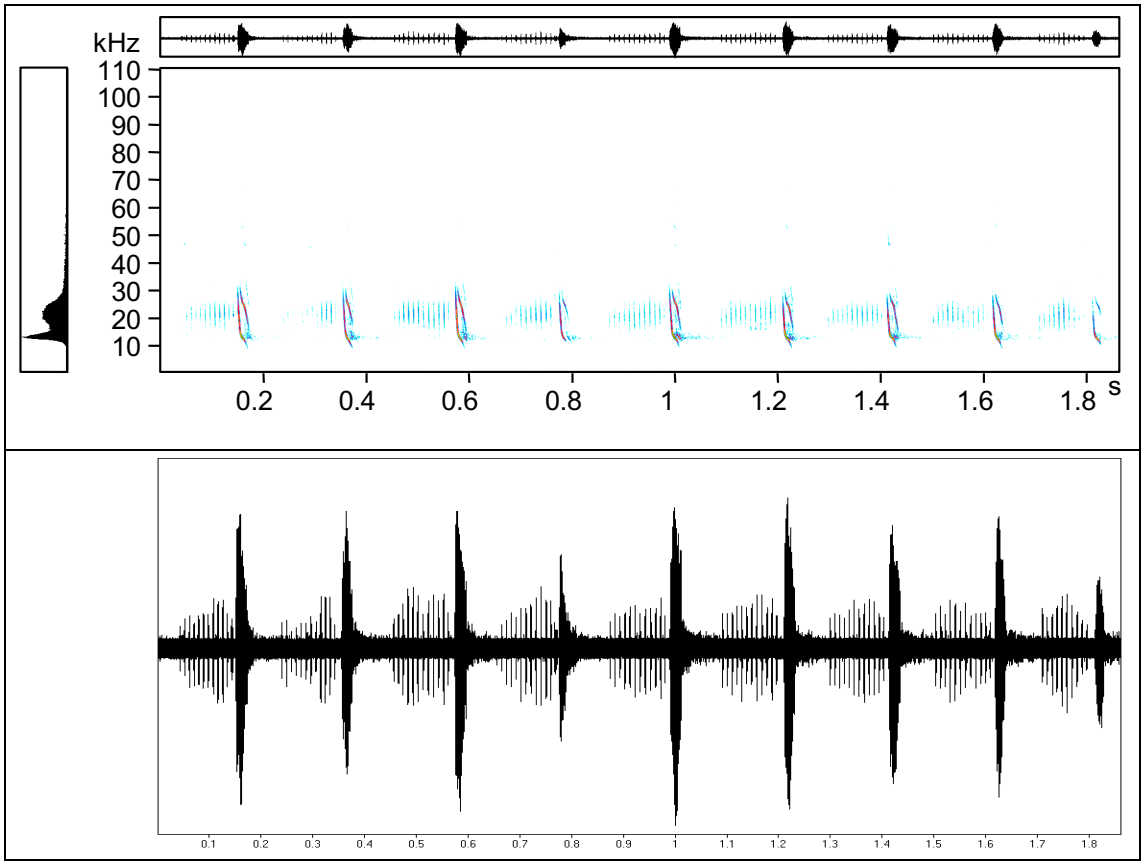


**Fig. 5.2.1.12 a2:** Social calls of call type A from a Particoloured bat (*V. murinus*) in songflight (residential area with multi-storey buildings at Betzenberg in Kaiserslautern, 16 October 2000, 21:05; Above: sonagram of a call sequence with nine single calls; Below: oscillogram of an approximately 1.9 s long recording sequence with nine individual calls; repetition rate here about 5 Hz)

**Tab. 5.2.1.12 a:** Statistical parameters of call type A from the Particoloured bat (*V. murinus*) (L = "L-shaped" element at the end of the call)

| | Duration [ms] | Duration L [ms] | $F_{max}$ L [kHz] | $F_{start}$ L [kHz] | $F_{end}$ L [kHz] | Number elements | Call interval [ms] | Pulse interval [ms] |
|---|---|---|---|---|---|---|---|---|
| Sample size | 181 | 377 | 377 | 377 | 377 | 123 | 349 | 915 |
| **Median** | **180,000** | **22,100** | **12,920** | **36,606** | **8,613** | **7,000** | **132,100** | **10,200** |
| Minimum | 20,600 | 17,400 | 11,628 | 25,840 | 6,891 | 5,000 | 59,800 | 7,500 |
| Maximum | 213,600 | 27,900 | 15,073 | 49,526 | 11,197 | 11,000 | 292,300 | 14,500 |
| Lower quartile | 172,700 | 20,600 | 12,920 | 34,023 | 8,183 | 7,000 | 95,800 | 9,600 |
| Upper quartile | 185,200 | 23,200 | 13,351 | 40,052 | 9,044 | 8,000 | 200,900 | 10,400 |
| **Average** | **177,771** | **22,058** | **13,158** | **37,288** | **8,673** | **7,301** | **147,846** | **10,099** |
| Standard deviation | 16,789 | 1,934 | 0,545 | 4,334 | 0,818 | 1,108 | 56,865 | 0,814 |

# 5.2.1.13 Common Pipistrelle (*Pipistrellus pipistrellus*, SCHREBER, 1774)

Social calls from flying Common Pipistrelles were recorded at almost all recording sites, including Vogelwoog, Blechhammer and Gelterswoog, in settlements at illuminated streets and over parking areas, as well as in woodland far from human populated areas (see chapter 3.2). In addition, maternity roosts in the gym of a school in Ramstein and in the roof of the biology building of Kaiserslautern University were observed. On three other occasions, social calls of juvenile Common Pipistrelles were recorded: A) On the 22nd of August 2000 a cardboard box with young Common Pipistrelles, which had invaded an office building in Kaiserslautern's inner city ("Eisenbahnstraße"), was handed over to the author by a fire brigade employee. The animals were released on the same evening near the place of finding; B) On the 25th of August 2000, a mass invasion of *P. pipistrellus* took place at a multi-storey building in western Kaiserslautern. On behalf of the local environmental authority, the author and C. WEBER collected altogether 97 Common Pipistrelles from the staircase of the building, hidden behind curtains, in flowerpots, and in mailboxes. Some specimens escaped through a tilted window. In the evening, the - mainly juvenile - animals were released in a nearby park; C) On the 30th of May 2001, the author received from Mrs. BÖHM (Bruchmühlbach-Miesau) a gravid Common Pipistrelle with a damaged wing membrane. The female gave birth to a male juvenile two weeks later, whose calls were sporadically recorded. After evaluating the numerous call recordings, at least five call types can be distinguished in the Common Pipistrelle.

### A) Common Pipistrelle (*P. pipistrellus*): Call type A

The most conspicuous vocalisations of the Common Pipistrelle are the calls of call type A. They were recorded at various locations throughout the investigation period from 1998 to 2000, almost during the entire activity period from April to October, particularly in the months of August and September (Fig. 5.2.1.13 a1). Sometimes, foraging activity and the presence of several individuals in the same airspace were observed while recording these calls. During the mating season, individual patrolling animals were registered regularly integrating the described social calls into their echolocation call sequences. These are two to five (median: four) single pulses, which initially begin with a steep downward modulated part, and turn into a flat modulated end part. Sometimes, the end part of the single pulses is in turn upwards frequency-modulated, which results in a "hook-like" shape (Fig. 5.2.1.13 a2). The call duration varies within 175 measured calls corresponding to the number of call elements between approximately 15 ms and 42 ms (median: 29.6 ms). The peak frequency is in the audible range (median: 18.1 kHz), as well as the lowest frequency (median: 14.6 kHz). The duration of the single elements increases towards the end of the call, their $F_{max}$ remains more or less constant, and its lowest frequency decreases (Tab. 5.2.1.13 a).

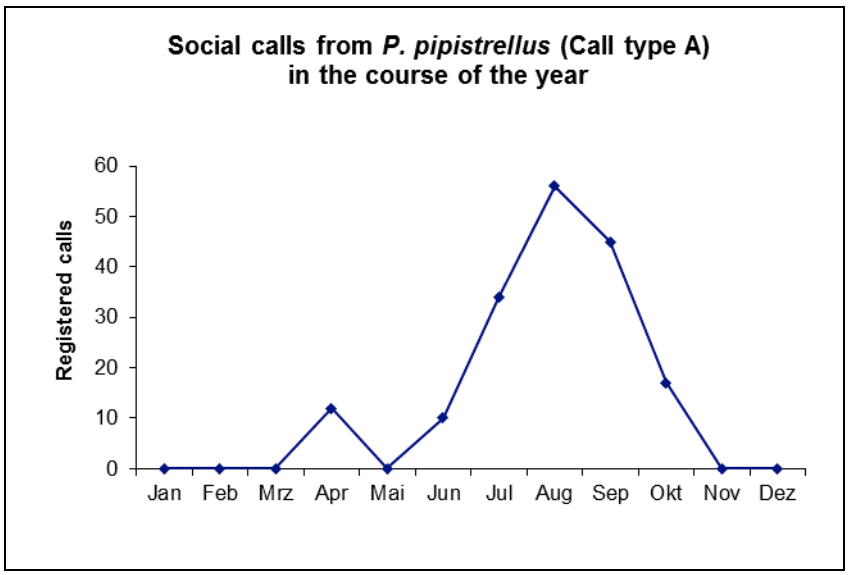


**Fig. 5.2.1.13 a1:** Registered social calls of call type A from the Common Pipistrelle (*P. pipistrellus*) in the course of the investigation period 1998 - 2000

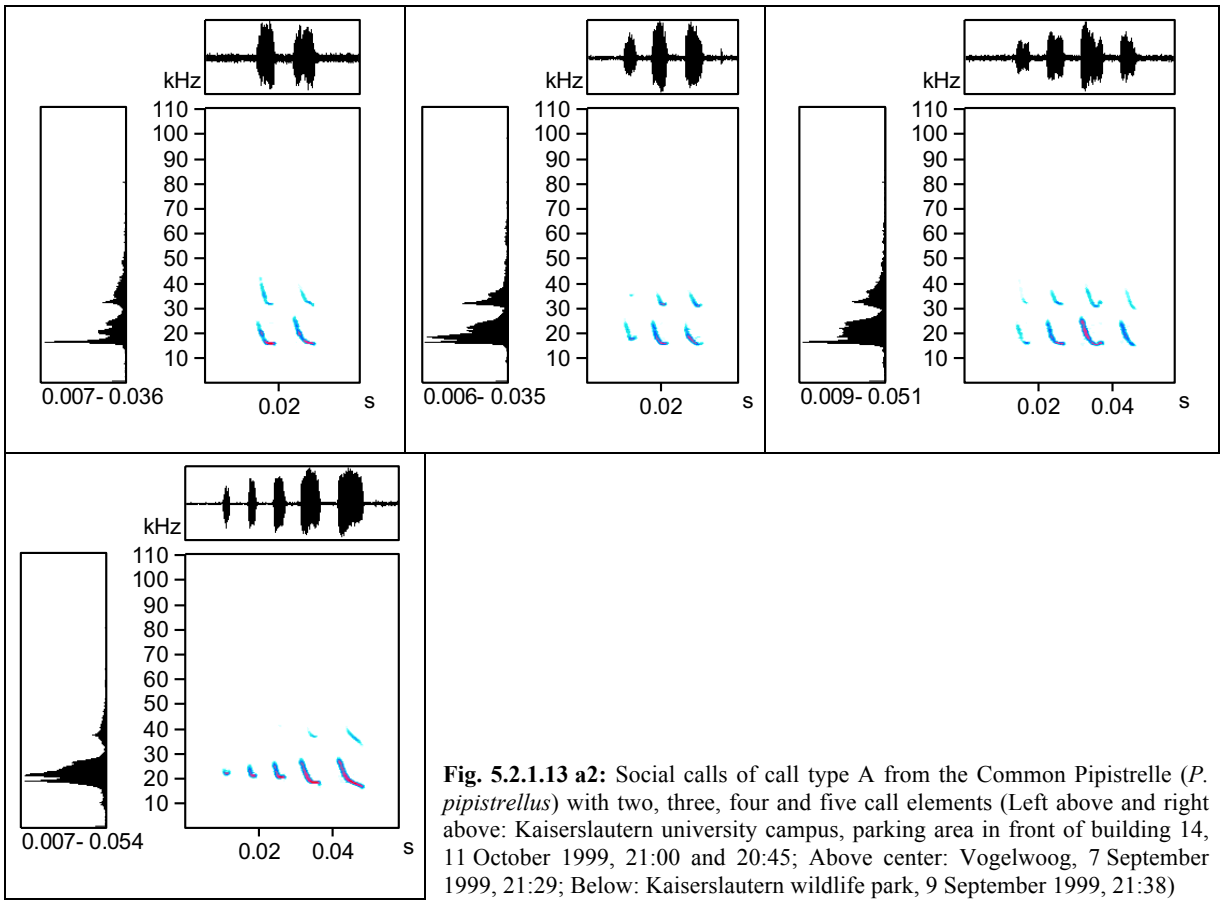


**Fig. 5.2.1.13 a2:** Social calls of call type A from the Common Pipistrelle (*P. pipistrellus*) with two, three, four and five call elements (Left above and right above: Kaiserslautern university campus, parking area in front of building 14, 11 October 1999, 21:00 and 20:45; Above center: Vogelwoog, 7 September 1999, 21:29; Below: Kaiserslautern wildlife park, 9 September 1999, 21:38)

**Tab. 5.2.1.13 a:** Statistical parameters of call type A from the Common Pipistrelle (*P. pipistrellus*)

| | Duration [ms] | $F_{max}$ [kHz] | $F_{start}$ [kHz] | $F_{end}$ [kHz] | Number elements |
|---|---|---|---|---|---|
| Sample size | 175 | 175 | 175 | 175 | 175 |
| **Median** | **29,600** | **18,088** | **29,716** | **14,643** | **4,000** |
| Minimum | 14,800 | 15,504 | 24,548 | 12,059 | 2,000 |
| Maximum | 42,100 | 21,964 | 59,001 | 17,227 | 5,000 |
| Lower quartile | 25,800 | 16,796 | 27,563 | 14,212 | 3,000 |
| Upper quartile | 33,400 | 19,380 | 31,008 | 15,504 | 4,000 |
| **Average** | **29,731** | **18,110** | **30,245** | **14,849** | **3,731** |
| Standard deviation | 5,912 | 1,481 | 4,492 | 0,937 | 0,789 |
| | | | | | |
| Duration [ms] | pulse 1 | pulse 2 | pulse 3 | pulse 4 | pulse 5 |
| Sample size | 175 | 175 | 167 | 107 | 29 |
| **Median** | **4,900** | **5,800** | **6,700** | **7,000** | **6,100** |
| Minimum | 2,600 | 3,500 | 3,800 | 2,900 | 3,500 |
| Maximum | 7,300 | 10,400 | 10,400 | 9,900 | 10,200 |
| Lower quartile | 4,400 | 5,200 | 6,100 | 6,100 | 5,200 |
| Upper quartile | 5,500 | 6,400 | 7,500 | 7,500 | 7,000 |
| **Average** | **4,921** | **5,892** | **6,869** | **6,948** | **6,372** |
| Standard deviation | 0,873 | 1,135 | 1,380 | 1,258 | 1,666 |
| | | | | | |
| $F_{max}$ [kHz] | pulse 1 | pulse 2 | pulse 3 | pulse 4 | pulse 5 |
| Sample size | 175 | 175 | 167 | 107 | 29 |
| **Median** | **18,087** | **17,657** | **18,088** | **18,519** | **18,949** |
| Minimum | 15,073 | 15,504 | 15,504 | 15,504 | 16,365 |
| Maximum | 22,825 | 22,395 | 21,964 | 22,395 | 21,533 |
| Lower quartile | 16,796 | 16,796 | 17,227 | 16,796 | 18,088 |
| Upper quartile | 19,811 | 18,949 | 19,380 | 19,811 | 20,241 |
| **Average** | **18,196** | **18,004** | **18,158** | **18,482** | **19,157** |
| Standard deviation | 1,694 | 1,584 | 1,504 | 1,622 | 1,538 |
| | | | | | |
| $F_{end}$ [kHz] | pulse 1 | pulse 2 | pulse 3 | pulse 4 | pulse 5 |
| Sample size | 175 | 175 | 167 | 107 | 29 |
| **Median** | **15,935** | **15,935** | **15,935** | **15,504** | **15,073** |
| Minimum | 12,920 | 12,059 | 12,920 | 12,920 | 12,920 |
| Maximum | 20,672 | 20,672 | 19,380 | 18,949 | 18,088 |
| Lower quartile | 15,073 | 15,073 | 14,643 | 14,643 | 14,643 |
| Upper quartile | 17,657 | 16,796 | 16,796 | 16,796 | 16,365 |
| **Average** | **16,402** | **16,072** | **15,999** | **15,782** | **15,400** |
| Standard deviation | 1,595 | 1,535 | 1,522 | 1,319 | 1,259 |

## B) Common Pipistrelle (*P. pipistrellus*): Call type B

The vocalisations of call type B are high-frequency sounds, which are sometimes integrated into echolocation sequences in combination with call type A. The calls show the same structure as echolocation calls, but the former's peak frequency is regularly 10 kHz higher. The chronology of emitted calls within a recording sequence proves that call type B originates from the "45 kHz

Common Pipistrelle" and not from the "high-calling" Soprano Pipistrelle (*P. pygmaeus*) (see also VICINUS 1997). In general, one single or sometimes two (or three) high-frequency calls of type B, emitted shortly one after another, were integrated into the echolocation call sequences (arrows in Fig. 5.2.1.13 b). At least two individuals were always present. The median call duration is 4.1 ms, the peak frequency varies within 25 measured calls between 52.5 kHz and 62.9 kHz (median: 57,7 kHz). The median of the lowest frequency is 56.4 kHz. In three cases, a social call of the call type A was emitted 115 - 124 ms before the high-frequency call type B. The "double calls" were registered ten times, with a median call interval of 33,3 ms (Tab. 5.2.1.13 b).

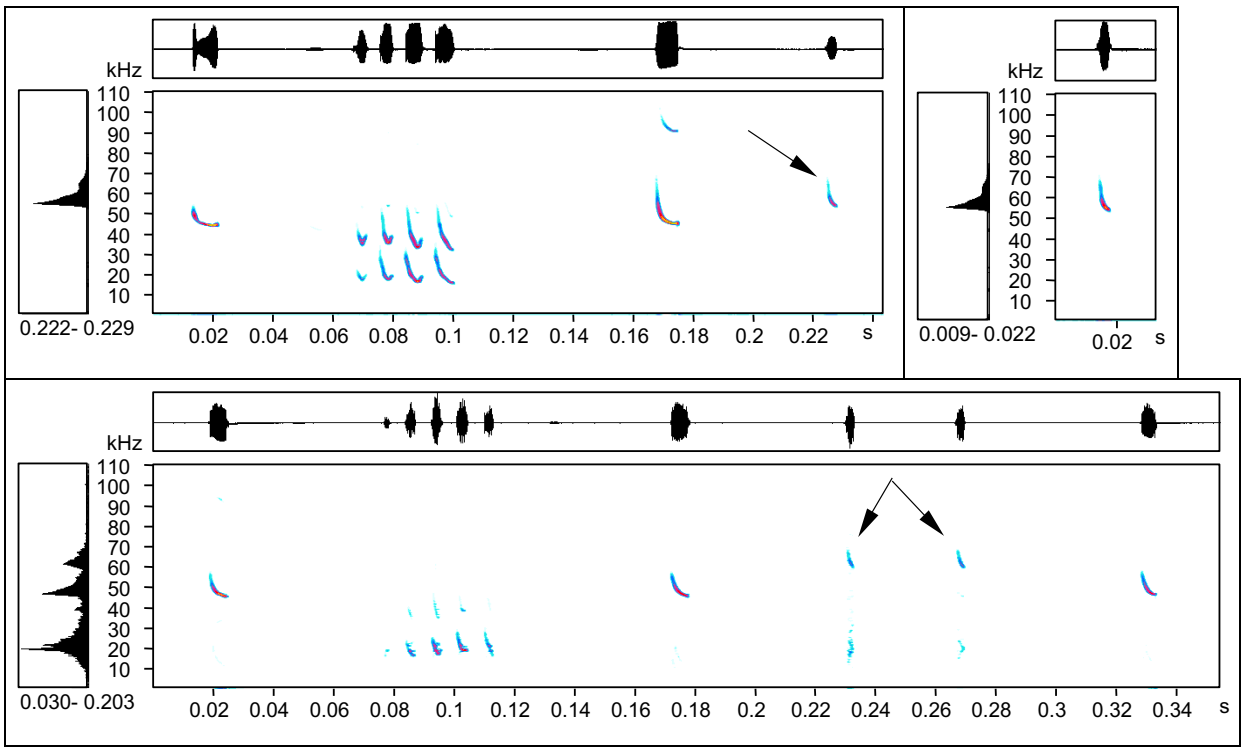


**Fig. 5.2.1.13 b:** High-frequency "echolocation-like" call of call type B from the Common Pipistrelle (*P. pipistrellus*), which are integrated into the echolocation call sequences (Above left: Integrated single call (arrow) with previous social call of type A, Vogelwoog, 4 June 1998, 22:45; Above right: Sonagram of a single high-frequency call of the Common Pipistrelle (*P. pipistrellus*), Vogelwoog, 4 June 1998, 22:45; Below: Integrated "double call" (arrows) with previous social call of call type A, Vogelwoog, 19 August 1999, 22:51)

**Tab. 5.2.1.13 b:** Statistical parameters of call type B from the Common Pipistrelle (*P. pipistrellus*)

| | Duration [ms] | $F_{max}$ [kHz] | $F_{start}$ [kHz] | $F_{end}$ [kHz] | Distance to call type A [ms] | Dist. before "double call" [ms] | Distance after "double call" [ms] | Pulse interval "double call" [ms] |
|---|---|---|---|---|---|---|---|---|
| Sample size | 25 | 25 | 25 | 25 | 3 | 10 | 10 | 10 |
| **Median** | **4,100** | **57,709** | **65,030** | **56,417** | **123,400** | **50,050** | **41,800** | **33,250** |
| Minimum | 2,600 | 52,541 | 61,585 | 50,818 | 114,900 | 45,600 | 34,000 | 24,100 |
| Maximum | 5,200 | 62,877 | 82,688 | 59,862 | 124,200 | 157,300 | 87,700 | 45,000 |
| Lower quartile | 3,500 | 56,417 | 63,738 | 54,694 | - | 48,200 | 36,000 | 29,300 |
| Upper quartile | 4,400 | 59,432 | 67,614 | 57,709 | - | 52,500 | 57,200 | 35,700 |
| **Average** | **3,928** | **57,950** | **66,684** | **56,090** | **120,833** | **62,490** | **47,560** | **33,200** |
| Standard deviation | 0,685 | 2,638 | 4,947 | 2,487 | 5,154 | 34,354 | 16,854 | 5,579 |

## C) Common Pipistrelle (*P. pipistrellus*): Call type C

The highly variable "bow-shaped" calls of type C were registered mainly at the two observed maternity colonies. There, animals inside the roosts emitted these calls while other bats swarmed in front of the buildings. Calls of flying individuals were recorded during the three years of investigation from the end of June / beginning of July until the middle of August, which is the time frame between the first flights of the juveniles and the dispersal of the maternity colonies. Frequently, "tandem flights" were observed while recording this type of call. Also an injured female's juvenile, born in captivity and kept under care of the author, occasionally emitted these calls from inside its roost while the mother was searching for mealworms in its cage and especially during the intense subsequent greeting ceremony when returning to the young. The elongated calls are initially steeply downward modulated and flattened in the further course. At the end of the call, an upward modulation follows sometimes, which in rare cases merges into a terminating CF-part. The "double calls" occur as a call variant (Fig. 5.2.1.13 c). The calls are often emitted in short call sequences. The call parameters are also highly variable within one and the same sequence. The median call duration of single calls is 15.4 ms (5.2 - 45.6 ms). Also the values for $F_{max}$ (median: 36.2 kHz), $F_{start}$ (median: 55.6 kHz) and $F_{end}$ (median: 32.5 kHz) vary very strongly in the 168 single calls analysed. The lowest frequency sometimes drops down to the audible range (minimum: 16.4 kHz). In the ten "double calls" evaluated, the first pulse is clearly longer and lower in frequency. The median interval between the two call elements is 9 ms (Tab. 5.2.1.13 c).

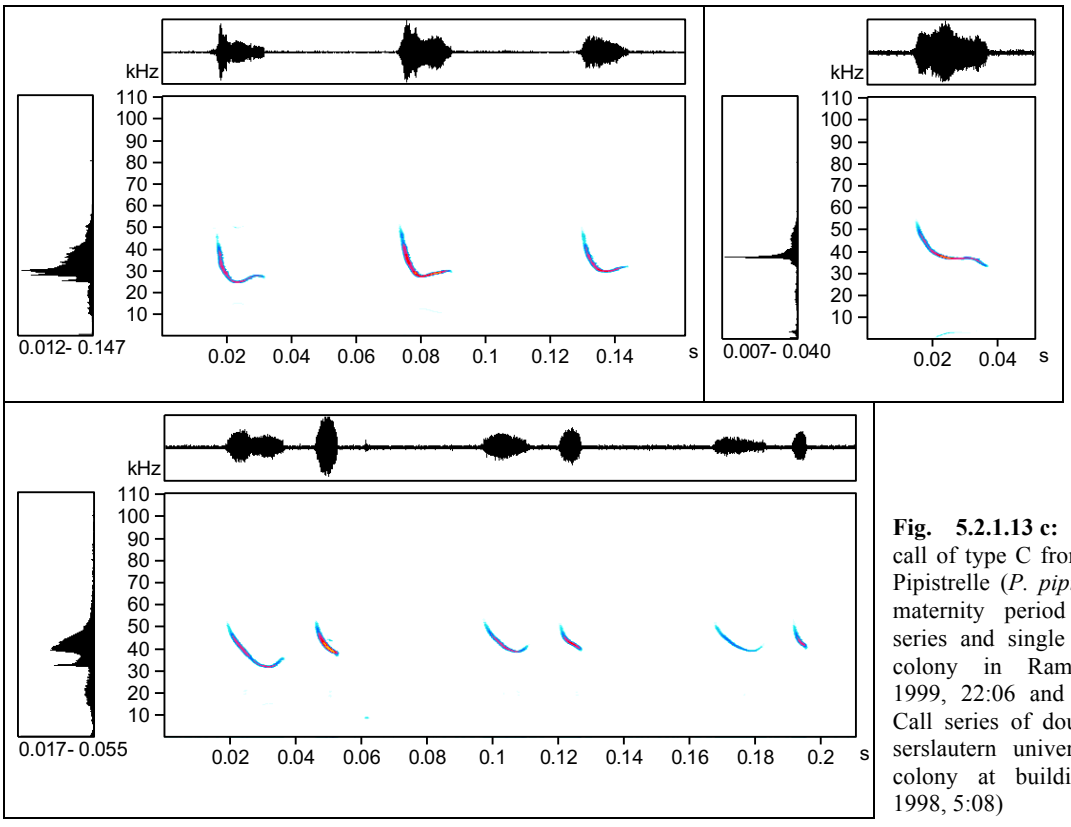


**Fig. 5.2.1.13 c:** "Bow-shaped" call of type C from the Common Pipistrelle (*P. pipistrellus*) in the maternity period (Above: Call series and single call, maternity colony in Ramstein, 26 June 1999, 22:06 and 22:32; Below: Call series of double calls, Kaiserslautern university, maternity colony at building 13, 6 July 1998, 5:08)

**Tab. 5.2.1.13 c:** Statistical parameters of call type C from the Common Pipistrelle (*P. pipistrellus*)

| **Single call** | Duration [ms] | $F_{max}$ [kHz] | $F_{start}$ [kHz] | $F_{end}$ [kHz] |
|---|---|---|---|---|
| Sample size | 168 | 168 | 168 | 168 |
| **Median** | **15,400** | **36,176** | **55,556** | **32,515** |
| Minimum | 5,200 | 20,241 | 40,913 | 16,365 |
| Maximum | 45,600 | 46,942 | 72,352 | 43,928 |
| Lower quartile | 12,200 | 32,731 | 51,464 | 29,501 |
| Upper quartile | 20,000 | 39,621 | 60,508 | 36,176 |
| **Average** | **17,031** | **36,014** | **55,958** | **32,377** |
| Standard deviation | 7,159 | 5,027 | 5,898 | 4,877 |

| **Double call** | Duration pulse 1 [ms] | $F_{max}$ pulse 1 [kHz] | $F_{start}$ pulse 1 [kHz] | $F_{end}$ pulse 1 [kHz] | Duration pulse 2 [ms] | $F_{max}$ pulse 2 [kHz] | $F_{start}$ pulse 2 [kHz] | $F_{end}$ pulse 2 [kHz] | Call pauses |
|---|---|---|---|---|---|---|---|---|---|
| Sample size | 10 | 10 | 10 | 10 | 10 | 10 | 10 | 10 | 10 |
| **Median** | **19,700** | **34,238** | **54,048** | **32,946** | **8,400** | **40,052** | **55,771** | **35,530** | **9,000** |
| Minimum | 15,400 | 31,008 | 49,526 | 30,147 | 5,200 | 35,745 | 49,096 | 30,147 | 7,500 |
| Maximum | 21,500 | 40,052 | 60,293 | 38,329 | 10,400 | 42,636 | 61,154 | 40,482 | 11,300 |
| Lower quartile | 18,900 | 32,731 | 53,833 | 31,439 | 7,800 | 37,468 | 53,833 | 33,161 | 8,400 |
| Upper quartile | 21,200 | 37,037 | 55,986 | 35,745 | 9,600 | 42,636 | 57,709 | 37,037 | 9,900 |
| **Average** | **19,500** | **34,970** | **54,910** | **33,764** | **8,350** | **39,750** | **55,556** | **35,444** | **9,310** |
| Standard deviation | 2,039 | 2,962 | 2,923 | 2,785 | 1,543 | 2,552 | 3,292 | 3,139 | 1,249 |

## D) Common Pipistrelle (*P. pipistrellus*): Call type D

Social calls of type D were also recorded at maternity roosts. Furthermore, the predominantly young bats collected after the invasion, emitted this type of call. In addition, it was registered from an adult injured female. The calls consist of a series of short FM or long CF pulses as well as all transitions between the two. Sometimes, no "clear" frequency response is articulated, but short pulses, consisting of multi-harmonic (chaotic) noise bands, are emitted, which in time-expansion sound like "cawing chatter" (Fig. 5.2.1.13 d1). As can be seen from the sonogram in figure 5.2.1.13 d2, in most cases long call series can be observed. The call duration varies considerably (17 - 146 ms). Peak frequency and lowest frequency are (as far as measurable) inside the audible range (median $F_{max}$: 18,9 kHz, median $F_{end}$: 15,9 kHz). The median pulse intervals are 5.5 ms for calls with FM pulses and 16.3 ms for calls with CF pulses (Tab. 5.2.1.13 d). The former are similar to the sound vocalisations of call type A, which are emitted in the foraging area or inside the mating territory.

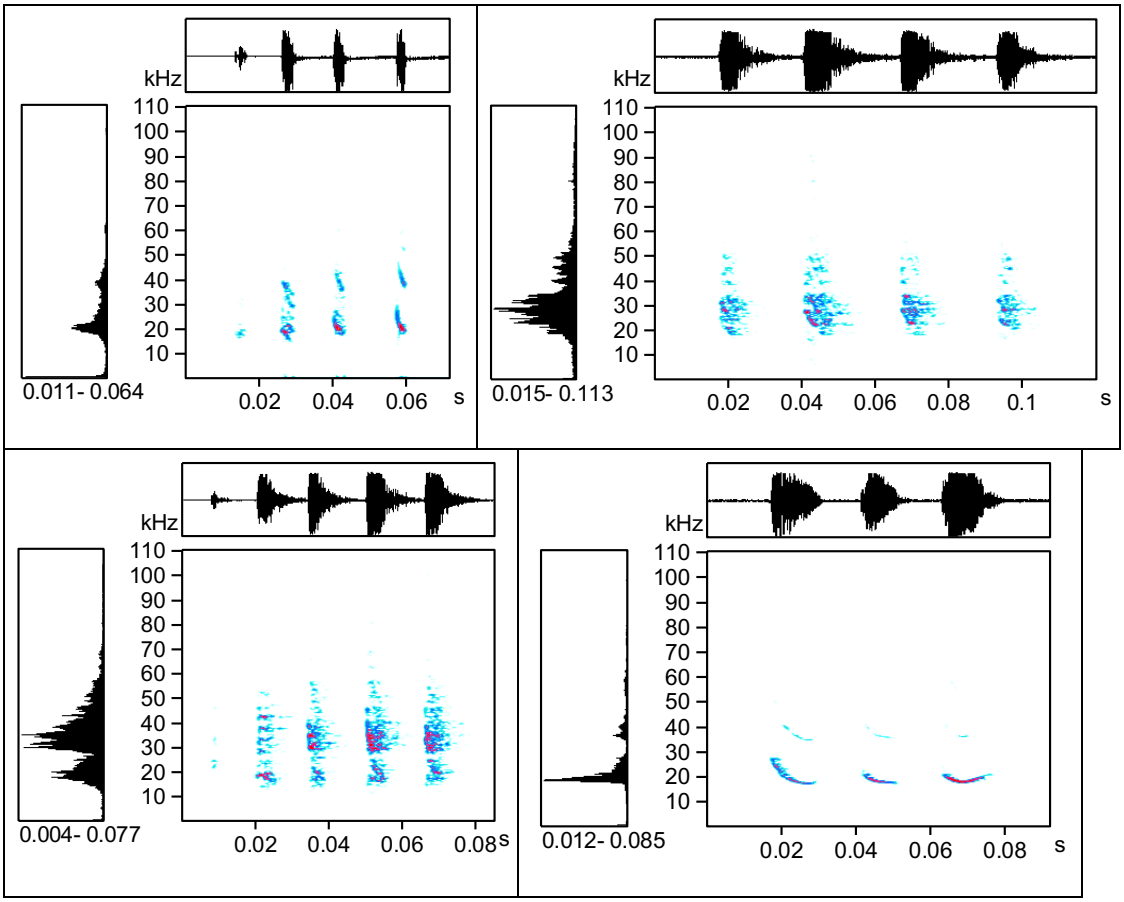


**Fig. 5.2.1.13 d1:** Social calls of call type D from the Common Pipistrelle (*P. pipistrellus*) (Above left: Maternity colony in Ramstein, 26 June 1999, 21:35; Above right and below left: Young animal from an "invasion" group of Common Pipistrelles, Kaiserslautern, 25 August 2000, 13:21 and 13:25; Below right: Young animal from another "invasion" group of Common Pipistrelles, Kaiserslautern, 22 August 2000, 16:57)

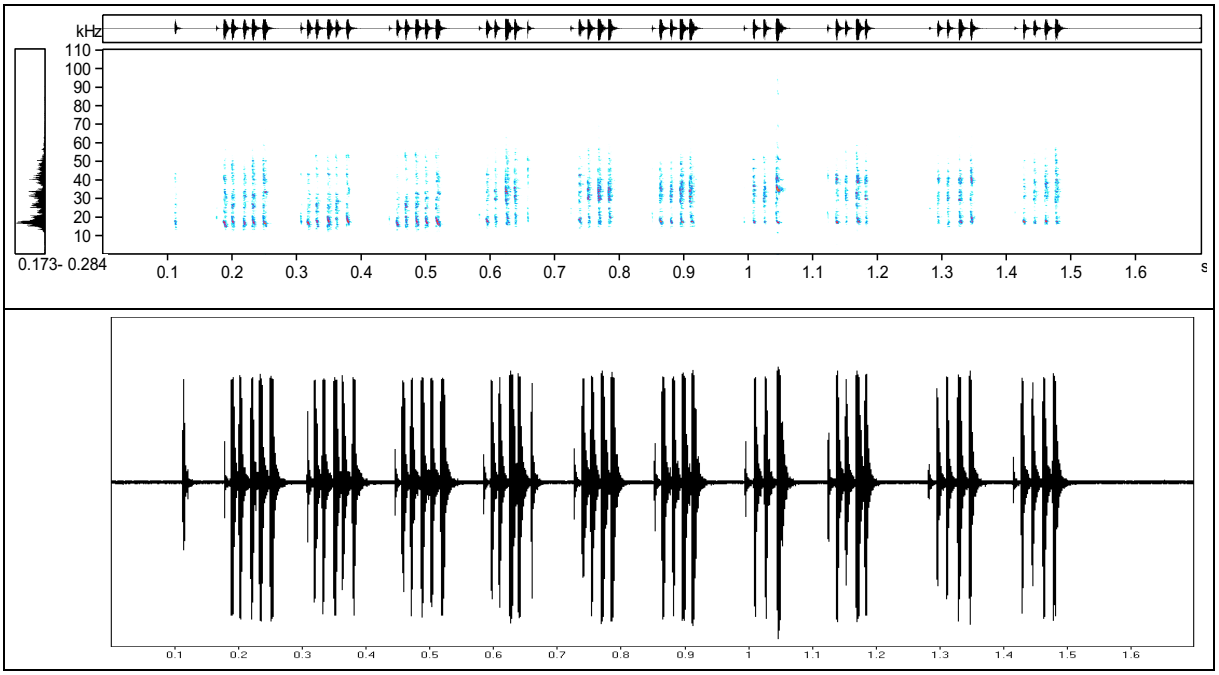


**Fig. 5.2.1.13 d2:** Social calls from a young Common Pipistrelle (*P. pipistrellus*) (animal from an "invasion" group, Kaiserslautern, 25 August 2000, 13:21; Above: Sonogram of a 1.6 s long call sequence with the corresponding oscillogram below)

**Tab. 5.2.1.13 d:** Statistical parameters of call type D from the Common Pipistrelle (*P. pipistrellus*)

| | Duration [ms] | $F_{max}$ [kHz] | $F_{end}$ [kHz] | Pulse interval short pulse [ms] | Pulse interval long pulse [ms] |
|---|---|---|---|---|---|
| Sample size | 28 | 175 | 123 | 64 | 31 |
| **Median** | **55,550** | **18,949** | **15,935** | **5,500** | **16,300** |
| Minimum | 17,100 | 15,504 | 12,920 | 3,200 | 8,700 |
| Maximum | 146,300 | 34,884 | 24,548 | 9,600 | 26,400 |
| Lower quartile | 49,200 | 17,657 | 15,073 | 4,600 | 13,400 |
| Upper quartile | 67,050 | 20,672 | 17,657 | 6,700 | 18,000 |
| **Average** | **61,361** | **19,707** | **16,516** | **5,714** | **16,113** |
| Standard deviation | 24,996 | 3,297 | 2,014 | 1,363 | 3,208 |

## E) Common Pipistrelle (*P. pipistrellus*): Call type E

"Cawing" calls of this call type were recorded from the captive-born Common Pipistrelle. They are also audible without a detector. Figure 5.2.1.13 e shows the sonogram of a call from a 14-day-old juvenile. The calls were obviously only emitted in case of distress, for which reason long-lasting recordings were avoided. No statistical parameters were determined because of the small database. The duration of the call shown in the sonogram is 95 ms, the peak frequency is about 27 kHz and the lowest frequency $F_{end}$ is about 17 kHz.

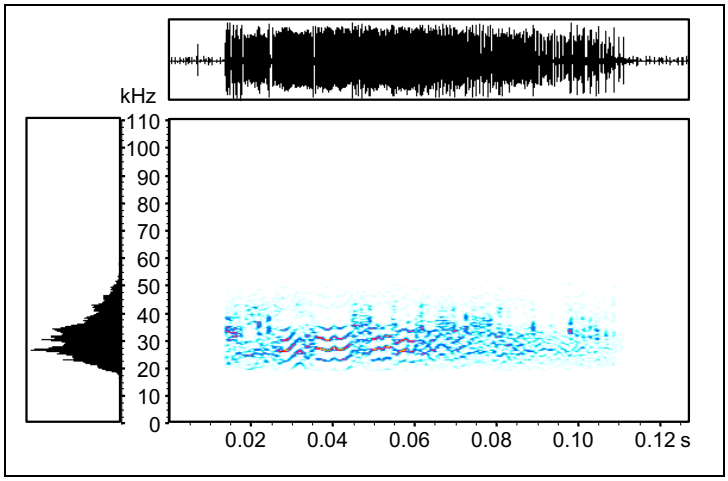


**Fig. 5.2.1.13 e:** Social calls (Call type E) from a 14-day-old Common Pipistrelle (*P. pipistrellus*) (Kaiserslautern, 27 June 2001, 20:41)

## 5.2.1.14 Soprano Pipistrelle (*Pipistrellus pygmaeus*, LEACH, 1825)

Within the scope of this work, social calls from the Soprano Pipistrelle were registered among others at Kaiserslautern Vogelwoog. Further recordings of *P. pygmaeus* worked out in October 1998 on the Spanish mediterranean coast near St. Feliú (Catalonia), where, incidentally, echolocation calls from the 45 kHz Common Pipistrelle (*P. pipistrellus*) were recorded, too. Finally, a song-flight sequence of *P. pygmaeus* was recorded in September 1999 at Bayreuth Hermitage, where the first record of the species for Bavaria was documented one year before (KOCH & VON HELVERSEN 2000). In addition to the already known "mating call" of the Soprano Pipistrelle, another call type can be described here.

### A) Soprano Pipistrelle (*P. pygmaeus*): Call type A

Social calls of type A were recorded on the 7th and the 15th of September 1999 at Kaiserslautern Vogelwoog and Bayreuth Hermitage. They correspond to the calls of *P. pygmaeus* recorded at the end of October 1998 on the Spanish Mediterranean coast. Call type A consists of a series of three (rarely four) individual pulses, which initially modulate steeply downward and end in a flat, modulated part (Fig. 5.2.1.14 a). The call duration of the 13 measured calls is in median 27.3 ms. The peak frequency is between 20.2 kHz and 23.3 kHz (median: 22 kHz). It is thus about 4 kHz higher than with call type A of *P. pipistrellus*. The lowest call frequency can drop down to 16.4 kHz (median: 18.1 kHz) (Tab. 5.2.1.14 a).

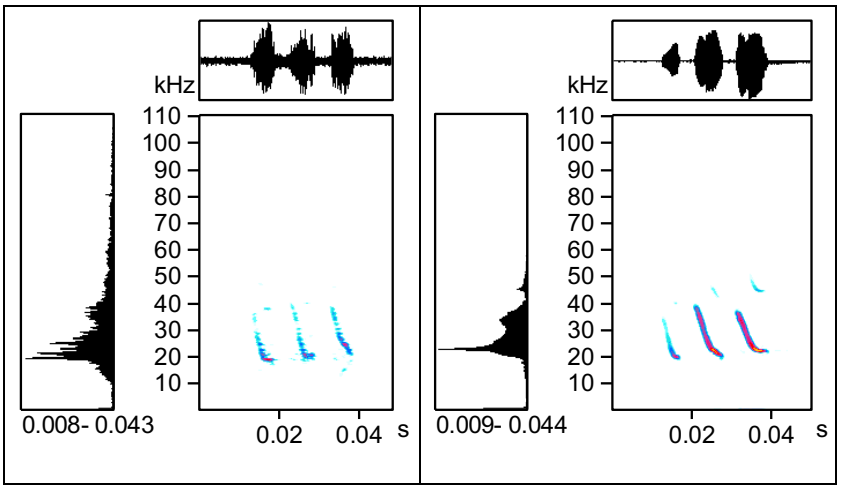


**Fig. 5.2.1.14 a:** Social calls of call type A from the Soprano Pipistrelle (*P. pygmaeus*) (Left: Kaiserslautern, Vogelwoog, 7 September 1999, 21:57; Right: Bayreuth, Hermitage, 15 September 1999, 21:07)

**Tab. 5.2.1.14 a:** Statistical parameters of call type A from the Soprano Pipistrelle (*P. pygmaeus*)

| | Duration [ms] | $F_{max}$ [kHz] | $F_{start}$ [kHz] | $F_{end}$ [kHz] |
|---|---|---|---|---|
| Sample size | 13 | 13 | 13 | 13 |
| **Median** | **27,300** | **21,964** | **40,482** | **18,088** |
| Minimum | 21,200 | 20,241 | 38,329 | 16,365 |
| Maximum | 28,700 | 23,256 | 49,096 | 18,519 |
| Lower quartile | 27,000 | 21,103 | 39,621 | 17,657 |
| Upper quartile | 28,400 | 22,395 | 41,774 | 18,519 |
| **Average** | **26,900** | **21,831** | **41,244** | **18,022** |
| Standard deviation | 2,220 | 0,850 | 2,764 | 0,605 |

| | Duration pulse 1 [ms] | Duration pulse 2 [ms] | Duration pulse 3 [ms] | $F_{max}$ pulse 1 [kHz] | $F_{max}$ pulse 2 [kHz] | $F_{max}$ pulse 3 [kHz] | $F_{end}$ pulse 1 [kHz] | $F_{end}$ pulse 2 [kHz] | $F_{end}$ pulse 3 [kHz] | Call pauses [ms] |
|---|---|---|---|---|---|---|---|---|---|---|
| Sample size | 13 | 13 | 13 | 13 | 13 | 13 | 13 | 13 | 13 | 8 |
| **Median** | **5,800** | **7,500** | **9,600** | **19,811** | **20,672** | **21,964** | **18,519** | **18,949** | **20,241** | **577,150** |
| Minimum | 4,400 | 6,700 | 6,400 | 19,380 | 19,811 | 21,103 | 16,796 | 17,657 | 18,519 | 314,100 |
| Maximum | 6,400 | 8,700 | 11,900 | 20,672 | 22,395 | 23,256 | 18,949 | 19,380 | 21,103 | 837,700 |
| Lower quartile | 5,200 | 7,300 | 9,000 | 19,811 | 20,241 | 21,533 | 18,088 | 18,519 | 19,811 | 494,900 |
| Upper quartile | 6,100 | 8,400 | 9,900 | 20,241 | 21,103 | 22,395 | 18,519 | 19,380 | 20,672 | 632,900 |
| **Average** | **5,646** | **7,738** | **9,438** | **19,943** | **20,771** | **22,063** | **18,254** | **18,784** | **20,208** | **570,213** |
| Standard deviation | 0,705 | 0,681 | 1,298 | 0,444 | 0,749 | 0,638 | 0,597 | 0,571 | 0,669 | 151,921 |

## B) Soprano Pipistrelle (*P. pygmaeus*): Call type B

These 'bow-shaped' calls, similar to those of call type C in *P. pipistrellus*, were recorded only in one sequence on the 24th of October 1998 at the Spanish Mediterranean coast. While recording, two bats were observed flying close behind one another ("tandem flight"). The five "bow calls" of this sequence are elongated, initially steeply modulated downwards and increasingly flattened towards the end of the call (Fig. 5.2.1.14 b). The call duration is 16.5 - 22.3 ms (median: 19.4 ms) and the median peak frequency is 31 kHz. The calls cover a frequency range of approximately 56 - 22 kHz (maximum-minimum values: 67.2 - 19.9 kHz) and are thus completely outside the human audible range (Tab. 5.2.1.14 b).

**Tab. 5.2.1.14 b:** Statistical parameters of call type B from the Soprano Pipistrelle (*P. pygmaeus*)

| | Duration [ms] | $F_{max}$ [kHz] | $F_{start}$ [kHz] | $F_{end}$ [kHz] |
|---|---|---|---|---|
| Sample size | 5 | 5 | 5 | 5 |
| **Median** | **19,400** | **31,008** | **56,417** | **21,533** |
| Minimum | 16,500 | 25,409 | 50,388 | 19,949 |
| Maximum | 22,300 | 32,300 | 67,184 | 22,395 |
| Lower quartile | 18,000 | 31,008 | 55,986 | 21,103 |
| Upper quartile | 20,000 | 31,869 | 66,322 | 21,533 |
| **Average** | **19,240** | **30,319** | **59,259** | **21,303** |

| | | | | |
|---|---|---|---|---|
| Standard deviation | 2,180 | 2,801 | 7,249 | 0,890 |

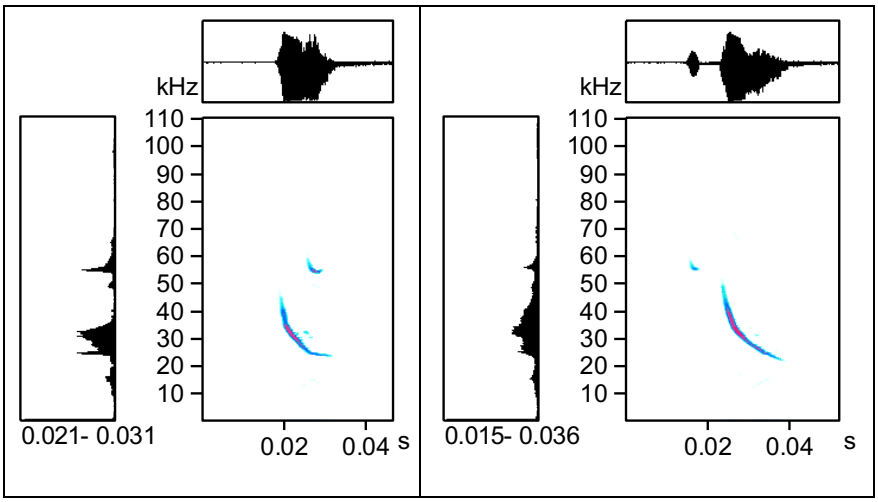


**Fig. 5.2.1.14 b:** "Bow-shaped" social calls of call type B from the Soprano Pipistrelle (*P. pygmaeus*) during an observed tandem flight; An echolocation call of the second animal can be seen on the sonogram (St. Feliú, Catalonia, 24 October 1998, 20:47)

## 5.2.1.15 Nathusius' Pipistrelle (*Pipistrellus nathusii*, KEYSERLING & BLASIUS, 1839)

Recordings of social calls from the Nathusius' Pipistrelle were carried out at the waters Kaiserslautern Vogelvoog and Gelterswoog exclusively during spring migration in April. Generally, these calls were observed when several animals foraged on the shore of the standing waters simultaneously. In one case, an interspecific interaction by means of social calls occurred between a *P. nathusii* and a *P. pipistrellus*. During the mating period in September, social calls from Nathusius' Pipistrelle were recorded at a batbox near Neuhofen (Upper Rhine Rift) and at Gießen "Philosophenwald". Four call types have been defined, with types B and C presumably being variants of A.

### A) Nathusius' Pipistrelle (*P. nathusii*): Call type A

The characteristic social call of type A consists of three parts: (A) a low-frequency trill of contiguous FM pulses (partially "V-shaped"); B) a short and steeply downward frequency-modulated middle part - sometimes with a harmonic and then reminding of the echolocation call of a long-eared bat (*Plecotus* sp.) and C) a final high-frequency trill (Fig 5.2.1.15 a). The total duration of the call is 129 - 177 ms (median: 143.8 ms) and the peak frequency sometimes is within the audible range (16.8 - 23.3 kHz, median: 18.5 kHz). The first call section can possibly contain very high frequency components. In the case of calls from a batbox at Neuhofen (Upper Rhine Rift), an $F_{start}$ of up to 105 kHz was measured (Fig. 5.2.1.15 a). The lowest frequency is always in the audible frequency range with a median of 13.8 kHz (Tab. 5.2.1.15 a, cf. also call types B and C).

**Tab. 5.2.1.15 a:** Statistical parameters of call type A from the Nathusius' Pipistrelle (*P. nathusii*)

| | Duration [ms] | $F_{max}$ [kHz] | $F_{start}$ [kHz] | $F_{end}$ [kHz] | Duration deeper trill [ms] | $F_{max}$ deeper trill [kHz] | $F_{start}$ deeper trill [kHz] | $F_{end}$ deeper trill [kHz] |
|---|---|---|---|---|---|---|---|---|
| Sample size | 14 | 14 | 14 | 14 | 14 | 14 | 14 | 14 |
| **Median** | **143,800** | **18,519** | **55,771** | **13,781** | **49,200** | **18,519** | **34,669** | **13,351** |
| Minimum | 128,600 | 16,796 | 40,913 | 11,197 | 32,200 | 16,796 | 26,701 | 11,628 |
| Maximum | 177,100 | 23,256 | 105,513 | 14,212 | 71,400 | 23,256 | 105,513 | 14,643 |
| Lower quartile | 139,600 | 17,657 | 49,096 | 13,351 | 46,400 | 17,657 | 29,716 | 13,351 |
| Upper quartile | 160,800 | 20,241 | 85,272 | 14,212 | 51,400 | 20,241 | 86,133 | 14,212 |
| **Average** | **149,514** | **19,011** | **66,784** | **13,443** | **48,157** | **19,134** | **53,802** | **13,412** |
| Standard deviation | 14,103 | 1,932 | 22,019 | 0,958 | 9,480 | 2,115 | 31,312 | 0,892 |

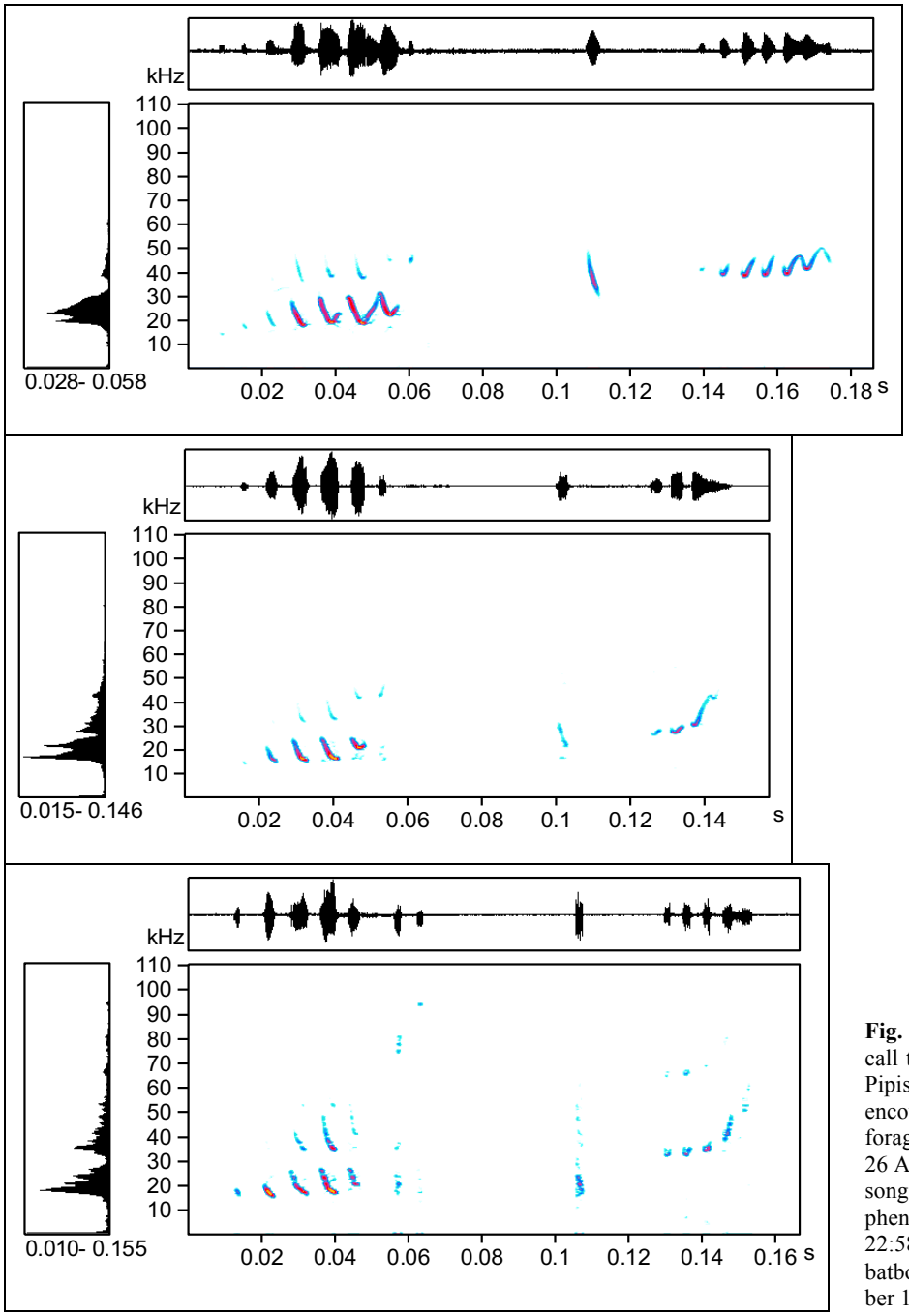


**Fig. 5.2.1.15 a:** Social calls of call type A from the Nathusius' Pipistrelle (*P. nathusii*) (Above: encounter of two animals in the foraging area, Gelterswoog, 26 April 1999, 21:50; Middle: song-flight at Gießen "Philosophenwald", 11 September 1999, 22:58; Below: call from inside a batbox, Neuhofen, 18 September 1999, 20:10)

## B) Nathusius' Pipistrelle (*P. nathusii*): Call type B

Presumably as a variant of call type A, this social call waqs recorded in April at Vogelwoog and Gelterswoog. It consists of a short, steeply downward FM pulse (sometimes with a harmonic) and a subsequent high-frequency trill (Fig. 5.2.1.15 b). There were always at least two *P. nathusii* in the operating range of the detector. In one case, an interspecific interaction of a *P. nathusii* with a *P. pipistrellus* was observed. In the recorded sequence, both animals emit social calls. As figure 5.2.1.15 b shows, the final high-frequency trill element is highly variable. In the sonograms shown, the call frequency differs by more than 15 kHz.

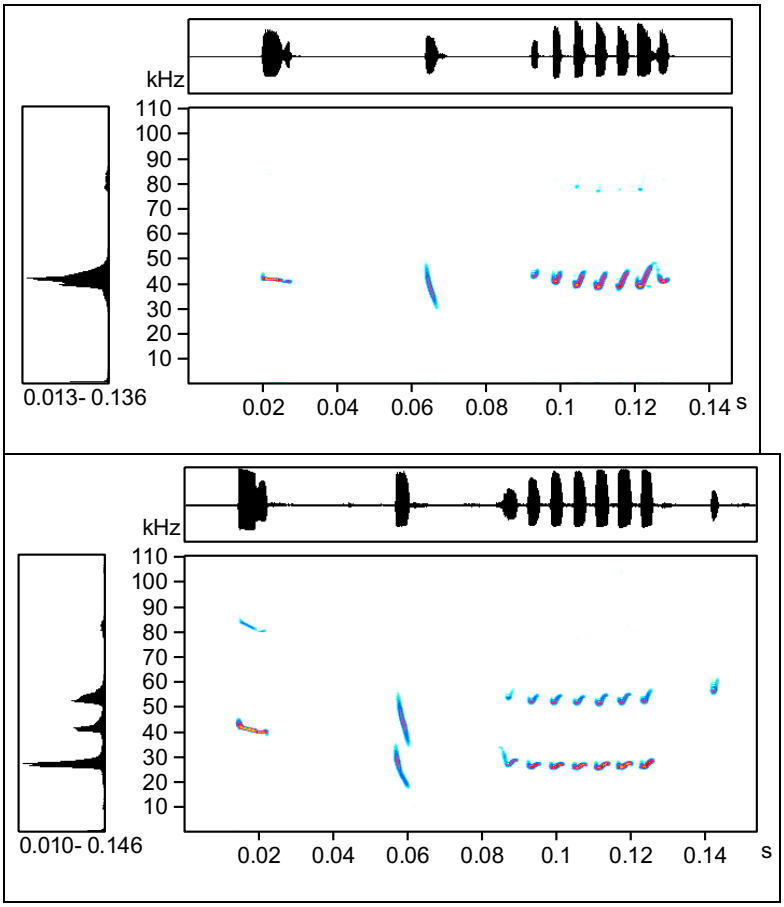


**Fig. 5.2.1.15 b:** Social calls of call type B from Nathusius' Pipistrelle (*P. nathusii*) at an encounter of two animals in the foraging area (Above: Gelterswoog, sandy shore, 26 April 1999, 21:50; Below: Gelterswoog, reed zone, 27 April 1999, 23:47; An echolocation call from the same bat is shown at the beginning of each sequence)

**Tab. 5.2.1.15 b:** Statistical parameters of call type B from Nathusius' Pipistrelle (*P. nathusii*)

| | Duration [ms] | $F_{max}$ [kHz] | $F_{start}$ [kHz] | $F_{end}$ [kHz] | Duration trill [ms] | $F_{max}$ trill [kHz] | $F_{start}$ trill [kHz] | $F_{end}$ trill [kHz] | Distance FM-pulse trill [ms] |
|---|---|---|---|---|---|---|---|---|---|
| Sample size | 5 | 5 | 5 | 5 | 19 | 19 | 19 | 19 | 19 |
| **Median** | **67,900** | **39,621** | **46,512** | **20,672** | **31,300** | **37,898** | **51,680** | **35,315** | **20,900** |
| Minimum | 61,800 | 27,132 | 44,358 | 13,351 | 20,300 | 27,132 | 35,315 | 24,117 | 18,900 |
| Maximum | 72,000 | 45,650 | 60,724 | 27,132 | 46,700 | 46,512 | 67,614 | 44,358 | 31,900 |
| Lower quartile | 63,000 | 38,329 | 44,358 | 16,796 | 25,000 | 33,161 | 47,804 | 29,716 | 19,700 |
| Upper quartile | 69,700 | 40,913 | 57,709 | 21,103 | 38,900 | 40,482 | 60,293 | 37,037 | 24,100 |
| **Average** | **66,880** | **38,329** | **50,732** | **19,811** | **31,984** | **36,901** | **53,493** | **33,773** | **22,021** |
| Standard deviation | 4,361 | 6,843 | 7,867 | 5,168 | 7,787 | 5,973 | 9,072 | 6,172 | 3,370 |

## C) Nathusius' Pipistrelle (*P. nathusii*): Call type C

The middle part of call type A can also be emitted discretely as an independent social call by *P. nathusii* (Fig. 5.2.1.15 c). The vocalisation is very similar to the echolocation calls of long-eared bats (*Plecotus* sp.). However, as with call type B, the relatively constant distance from the previous echolocation call (median: 37.6 ms) is striking. In all recorded sequences, this call pattern was recognisable. The highly variable peak frequency between 18 kHz and 37 kHz (median: 31 kHz) also contradicts an echolocation call from *Plecotus*. Table 5.2.1.15 c shows the statistical parameters of 27 measured calls.

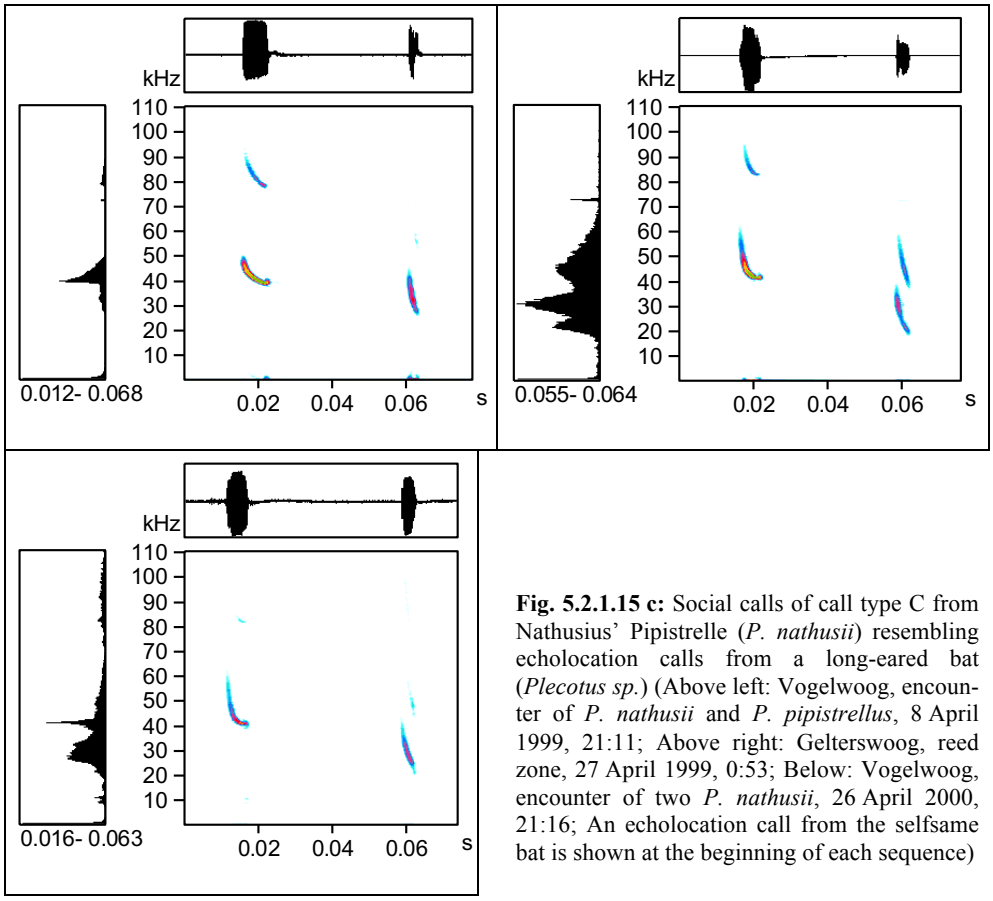


**Fig. 5.2.1.15 c:** Social calls of call type C from Nathusius' Pipistrelle (*P. nathusii*) resembling echolocation calls from a long-eared bat (*Plecotus sp.*) (Above left: Vogelwoog, encounter of *P. nathusii* and *P. pipistrellus*, 8 April 1999, 21:11; Above right: Gelterswoog, reed zone, 27 April 1999, 0:53; Below: Vogelwoog, encounter of two *P. nathusii*, 26 April 2000, 21:16; An echolocation call from the selfsame bat is shown at the beginning of each sequence)

**Tab. 5.2.1.15 c:** Statistical parameters of call type C from Nathusius' Pipistrelle (*P. nathusii*)

| | Duration [ms] | $F_{max}$ [kHz] | $F_{start}$ [kHz] | $F_{end}$ [kHz] | silent period before FM-pulse [ms] | silent period after FM-pulse [ms] |
|---|---|---|---|---|---|---|
| Sample size | 27 | 27 | 27 | 27 | 14 | 10 |
| **Median** | **5,200** | **31,008** | **46,512** | **17,657** | **37,600** | **75,900** |
| Minimum | 3,200 | 18,088 | 26,701 | 13,351 | 32,800 | 52,200 |
| Maximum | 6,700 | 37,037 | 62,016 | 27,132 | 53,100 | 102,200 |
| Lower quartile | 4,600 | 27,563 | 40,052 | 15,504 | 34,000 | 68,500 |
| Upper quartile | 5,800 | 34,884 | 48,665 | 21,533 | 39,800 | 90,000 |
| **Average** | **5,152** | **30,035** | **44,693** | **19,252** | **38,529** | **77,670** |
| Standard deviation | 0,923 | 5,255 | 8,893 | 4,557 | 5,525 | 16,301 |

## D) Nathusius' Pipistrelle (*P. nathusii*): Call type D

On the 18th of September 1999 a batbox monitoring near Neuhofen was carried out in the afternoon. At a roost occupied by two *P. nathusii*, social calls of this call type were recorded right before the inhabitants flew out at dusk. The calls are downward frequency-modulated with a clear harmonic. In one case, a "double call" was emitted. "Cawing" call parts with noise-bands were also recorded (Fig. 5.2.1.15 d). For the sake of completeness, the statistical parameters of the few evaluated calls are shown in Table 5.2.1.15 d. The most constant parameter is the lowest frequency $F_{end}$ (median: 15.5 kHz).

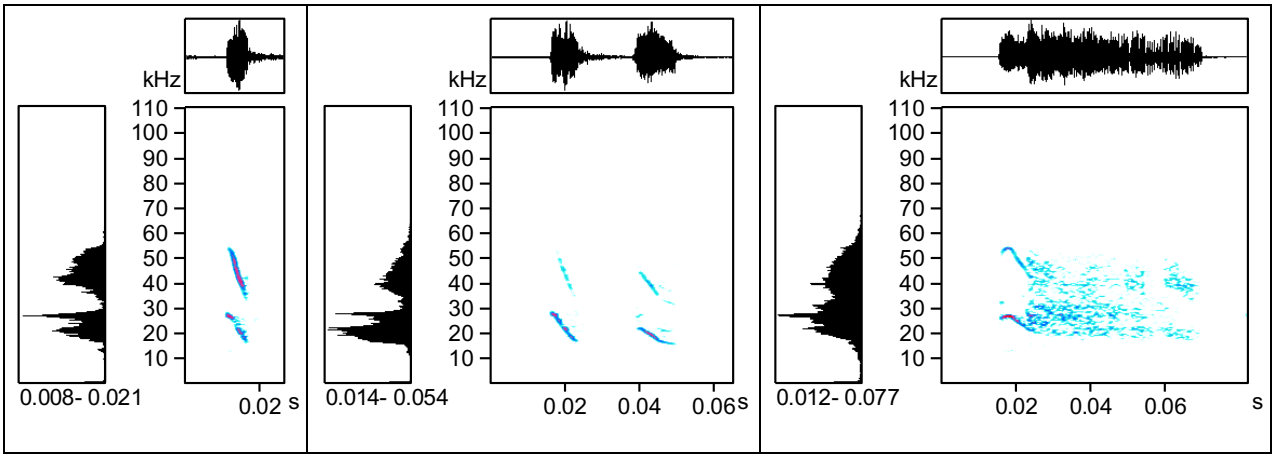


**Fig. 5.2.1.15 d:** Social calls of call type D from Nathusius' Pipistrelle (*P. nathusii*) shortly before flying out of the roost (batbox near Neuhofen with two *P. nathusii*, 18 September 1999, 20:12)

**Tab. 5.2.1.15 d:** Statistical parameters of call type D from Nathusius' Pipistrelle (*P. nathusii*)

| | Duration [ms] | $F_{max}$ [kHz] | $F_{start}$ [kHz] | $F_{end}$ [kHz] |
|---|---|---|---|---|
| Sample size | 3 | 3 | 2 | 3 |
| **Median** | **12,800** | **26,701** | **26,917** | **15,504** |
| Minimum | 9,600 | 21,103 | 23,687 | 14,643 |
| Maximum | 55,400 | 27,563 | 30,147 | 15,935 |
| Lower quartile | - | - | - | - |
| Upper quartile | - | - | - | - |
| **Average** | **25,933** | **25,122** | **26,917** | **15,360** |
| Standard deviation | 25,569 | 3,508 | 4,568 | 0,658 |

# 5.2.1.16 Kuhl's Pipistrelle (*Pipistrellus kuhlii*, KUHL, 1817)

Social calls from Kuhl's Pipistrelle were recorded on the Spanish Mediterranean and Atlantic coast. Two types of call were identified.

## A) Kuhl's Pipistrelle (*P. kuhlii*): Call type A

The most striking vocalisation of Kuhl's Pipistrelle (*P. kuhlii*) is the social call of type A. It usually consists of a series of two (rarely up to four) single pulses which initially modulate steeply downward and extend into a flat-modulated CF-part (Fig. 5.2.1.16 a). The median call duration of the 14 measured calls is 29.2 ms. The peak frequency ranges between 12.1 kHz and 16.4 kHz (median: 13.4 kHz) and is thus about 5 kHz lower than in *P. pipistrellus* call type A and about 8.5 kHz lower than in *P. pygmaeus* call type A. The lowest call frequency can drop down to 10.3 kHz (median: 11.8 kHz) (Tab. 5.2.1.16 a).

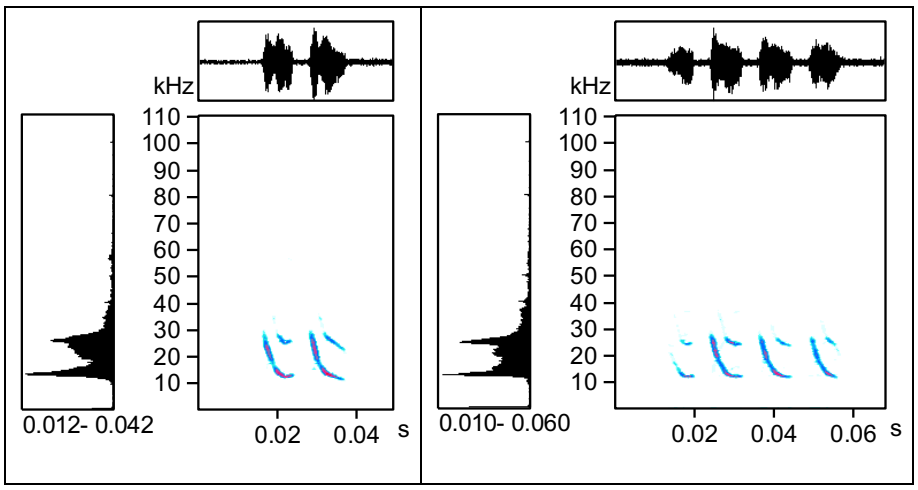


**Fig. 5.2.1.16 a:** Social calls of call type A from Kuhl's Pipistrelle (*P. kuhlii*) while foraging at streetlamps (St. Feliú, Catalonia, 17 October 1998, 19:34)

**Tab. 5.2.1.16 a:** Statistical parameters of call type A from Kuhl's Pipistrelle (*P. kuhlii*)

| | Duration [ms] | $F_{max}$ [kHz] | $F_{start}$ [kHz] | $F_{end}$ [kHz] | Number elements |
|---|---|---|---|---|---|
| Sample size | 14 | 14 | 14 | 14 | 14 |
| **Median** | **29,150** | **13,351** | **37,037** | **11,843** | **2,000** |
| Minimum | 19,400 | 12,059 | 30,577 | 10,336 | 1,000 |
| Maximum | 43,200 | 16,365 | 52,972 | 15,073 | 4,000 |
| Lower quartile | 27,300 | 12,920 | 34,453 | 11,197 | 2,000 |
| Upper quartile | 32,200 | 14,212 | 43,066 | 12,059 | 3,000 |
| **Average** | **30,371** | **13,843** | **39,713** | **11,905** | **2,286** |
| Standard deviation | 5,987 | 1,402 | 7,147 | 1,347 | 0,726 |
| | | | | | |
| Duration [ms] | 1st pulse | 2nd pulse | 3rd pulse | 4th pulse | |
| Sample size | 14 | 13 | 3 | 1 | |
| **Median** | **11,150** | **11,300** | **9,600** | **-** | |
| Minimum | 6,400 | 9,600 | 8,100 | 8,100 | |
| Maximum | 18,900 | 13,600 | 10,700 | 8,100 | |
| Lower quartile | 10,700 | 10,200 | - | - | |
| Upper quartile | 12,200 | 11,900 | - | - | |
| **Average** | **11,871** | **11,246** | **9,467** | **8,100** | |
| Standard deviation | 3,445 | 1,340 | 1,305 | - | |
| $F_{max}$ [kHz] | 1st pulse | 2nd pulse | 3rd pulse | 4th pulse | |
| Sample size | 14 | 13 | 4 | 1 | |
| **Median** | **13,351** | **13,351** | **13,566** | **-** | |
| Minimum | 12,489 | 12,059 | 12,489 | 12,920 | |
| Maximum | 16,365 | 16,365 | 13,781 | 12,920 | |
| Lower quartile | 12,920 | 12,920 | 12,920 | - | |
| Upper quartile | 14,212 | 13,781 | 13,781 | - | |
| **Average** | **13,874** | **13,682** | **13,351** | **12,920** | |
| Standard deviation | 1,243 | 1,317 | 0,609 | - | |
| | | | | | |
| $F_{end}$ [kHz] | 1st pulse | 2nd pulse | 3rd pulse | 4th pulse | |
| Sample size | 14 | 13 | 4 | 1 | |
| **Median** | **12,059** | **11,628** | **11,197** | **-** | |
| Minimum | 11,197 | 10,336 | 10,336 | 11,197 | |
| Maximum | 15,073 | 14,643 | 12,059 | 11,197 | |
| Lower quartile | 11,628 | 11,197 | 10,767 | - | |
| Upper quartile | 12,489 | 12,489 | 11,628 | - | |
| **Average** | **12,489** | **12,025** | **11,197** | **11,197** | |
| Standard deviation | 1,253 | 1,146 | 0,703 | - | |

## B) Kuhl's Pipistrelle (*P. kuhlii*): Call type B

The so-called "bow-shaped" calls also occur in this *Pipistrellus* species (see also *P. pipistrellus* and *P. pygmaeus*). The calls are elongated, initially steeply modulated and flattened in the further course. Sometimes, an upwards-modulated part follows at the end of the call (Fig. 5.2.1.16 b). The median call duration is 17.6 ms and the peak frequency is quite constant at about 28 kHz (27.6 - 29.3 kHz). The lowest frequency $F_{end}$, with a median of 20.2 kHz, can be within the audible range (Tab. 5.2.1.16 b).

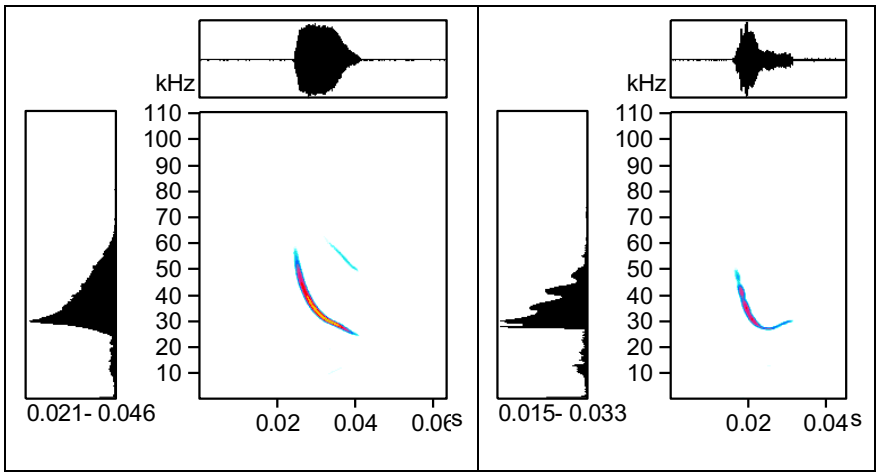


**Fig. 5.2.1.16 b:** "Bow-shaped" social call of call type B from Kuhl's Pipistrelle (*P. kuhlii*) in flight (Left: Tarifa, Andalusia, eroded sand dune on the coast, 11 March 2000, 20:59; Right: St. Feliú, Catalonia, foraging under streetlamps, 17 October 1998, 19:34)

**Tab. 5.2.1.16 b:** Statistical parameters of call type B from Kuhl's Pipistrelle (*P. kuhlii*)

| | Duration [ms] | $F_{max}$ [kHz] | $F_{start}$ [kHz] | $F_{end}$ [kHz] |
|---|---|---|---|---|
| Sample size | 4 | 4 | 4 | 4 |
| **Median** | **17,550** | **27,993** | **59,001** | **20,241** |
| Minimum | 16,000 | 27,563 | 55,125 | 13,781 |
| Maximum | 22,600 | 29,285 | 71,490 | 25,840 |
| Lower quartile | 16,550 | 27,778 | 55,125 | 15,719 |
| Upper quartile | 20,300 | 28,639 | 67,184 | 24,333 |
| **Average** | **18,425** | **28,209** | **61,154** | **20,026** |
| Standard deviation | 2,901 | 0,746 | 7,800 | 5,362 |