ChiRoPing Deliverable: D2.2.1

Title: Characterisation of call parameters and their variation with behaviour/task/phase for each bat species

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Dissemination:

Abstract:

Echolocation call parameters from the bat *Noctilio leporinus* from Panama were recorded using multi-microphone arrays. Calls were characterized as they change through a pursuit sequence from detection of the prey, through approach and localization of the prey to the terminal stage, the "buzz", right before capture. Echolocation calls emitted in the laboratory set-up were compared to calls emitted in the wild in *N.leporinus's* natural habitat.

Theme 2: Acoustic Modeling
WP 2.2 Capture and Analysis of Bat Calls sorted by Task

Deliverable due: Month **13**

Version: 1

Deliverables
Theme 2: Acoustic Modeling

D2.2.1 Characterization of call parameters and their variation with behavior/task/phase for each bat species (M8, M13, M24, M30) delivered incrementally as they are produced

D2.2.1 Characterization of call parameters and their variation with behavior/task/phase for *Noctilio leporinus*, the Greater Bulldog bat.

Introduction[1]

The recordings of the four bat species in this project must necessarily be done in the laboratory to make use of advanced equipment as multi-microphone arrays, and in-vivo, in-flight photo-scanning techniques. However, to be sure to sample data, that are biologically relevant for a bat negotiation obstacles and capturing prey in its natural field habitat, it is not only useful but indispensable to compare laboratory data with data sampled in the wild. Thus, we used the same procedure as for Daubenton's bat, *Myotis daubentonii* Vespertilionidae, when we recorded echolcation calls for the bulldog bat, *Noctilio leporinus*, recording calls from the wild as well as from the lab. We recorded *N.leporinus* capturing prey in a bay of Lake Gatún, Barro Colorado Island (BCI). Lab recordings were done in our new flight room on BCI, where the bats caught prey either on the surface or tethered 50-100 cm above an artificial pond.

Results I.
Field recordings of *Noctilio leporinus.*

1a

1b

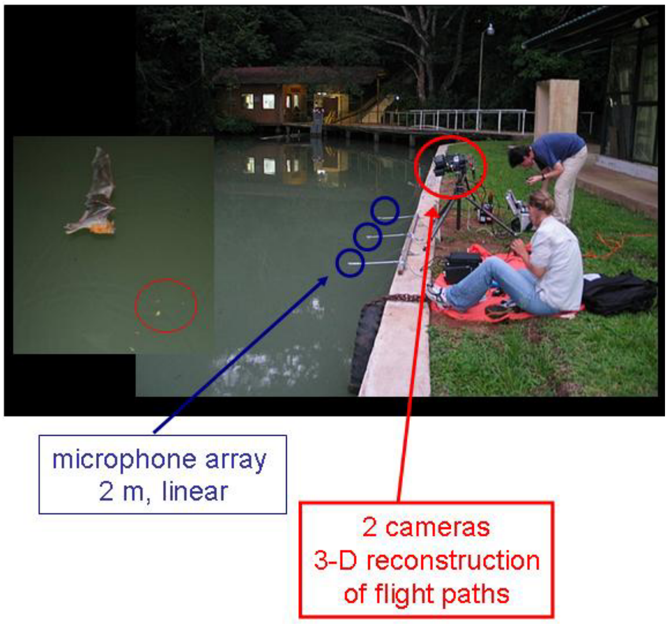
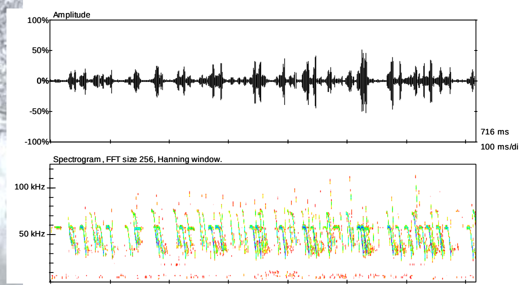


Figure 1. a) *Noctilio leporinus* flying in the wild over Lake Gatún, Panama. **b)** Recordings in the field were made using an array with 3 microphones (1/4" GRAS ultrasound microphones) 1 m apart. The array was placed at the brink of Lake Gatún, Panama, with the microphones 60 cm over the water surface.

[1] Delivered by Annemarie Surlykke, Signe Brinkløv, Biology, SDU, and all participants.

The microphone output was sampled on a laptop computer at 12 bit, 250 kHz with anti-aliasing filtering, using an IoTech Wavebook A/D converter with a pre-trigger system, which had a buffer memory (set to 3 s) allowing for manual triggering after a bat had passed the array at appropriate distance and direction. The bats were attracted by placing insects (mealworms) on the water surface (red circle in Fig.1b). The prey attracted many bats, which were hunting in close proximity. This presented an obvious problem: how can they detect and localize faint echoes from small prey items, when conspecific bats are emitting sonar calls at extreme sound pressures right next to them (Fig. 2)?



2b

2a

Figure 2. a) Multi-flash photo of a number of *N.leporinus* flying over the water in our study area. **b)** Oscillogram and spectrogram of a the echolocation sounds emitted in this scene, illustrating the sound (noise) level, which points to the perceptual challenges in detecting faint echoes in this situation.

N.leporinus is a big bat, average weight 50-70 g. Generally, insectivorous bats show a negative correlation between size and sonar call frequency, the larger the bat, the lower the frequency. Compared to its size *N.leporinus* emits calls with a high main frequency, 56 kHz. The call consists of a long almost constant frequency part followed by a negatively frequency moduled part sweeping down almost an octave.

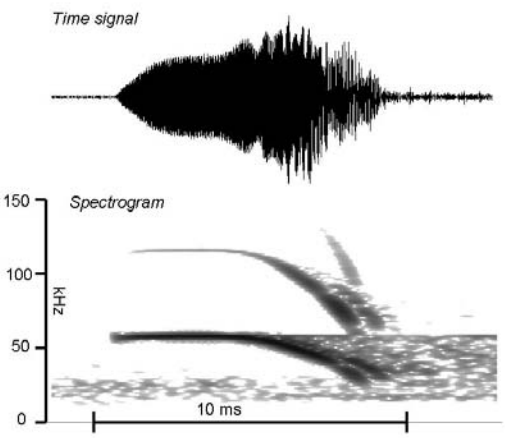
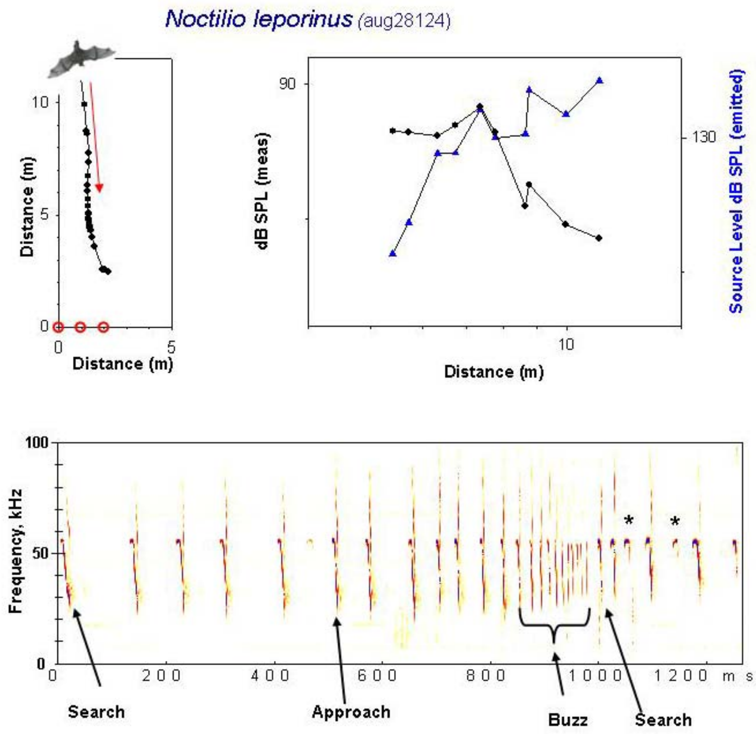


Figure 3. Search call of *Noctilio leporinus.* The almost-constant frequency part around 56 kHz is followed by a downward sweep.

We recorded pursuit sequences in the wild, and reconstructed the two-dimensional (2-D) flight paths based on the time-of-arrival-differences of the echolocation sounds at the microphones in the array (Fig.4). The pursuit consists of three marked phases: search, approach and terminal buzz. After the capture (-attempt) the bats return to search phase again. The bats actively control acoustic features of their sonar calls such as duration, frequency and bandwidth, call repetition rate and sweep rate to adapt to the changing challenges throughout the phases of the pursuit (Fig. 4).

Figure 4. Left panel shows a 2-D flight path seen from above, as the bat approached the microphones marked by red circles. The right graphs show measured and emitted sound pressures of search calls. Below are spectrograms of all echolocation calls during the hunting phases of this pursuit: search, approach and terminal phase.



In the wild *N.leporinus* search calls may be up to 18 ms in duration. The first harmonic is the most prominent with a constant frequency part around 56 kHz. The constant frequency is preceeded by a very short upward sweep and followed by a longer downward sweep down from 56 kHz to ca. 32 kHz. The bats may intersperse search sequences with calls with short terminal downward sweeps as for example the third and fifth call after the buzz (*) in Fig.4. When a potential prey is detected the bat enters the approach phase characterized by a decrease in call duration and an increase in repetition rate (Fig.4). The terminal phase, the “buzz”, where the call repetition rate is very high, up to 190 calls per second, is characterized by very short call durations of 1 ms or less. Unlike *M.daubentonii N.leporinus* does not have two distinct phases in its terminal buzz, but show gradual decrease in both call interval and call duration.

Results II.
Laboratory recordings of *Noctilio leporinus.*

In the laboratory we recorded the calls using a microphone array consisting of 12 microphones (ten 1/4” GRAS ultrasound microphones, two Avisoft). Ten of the microphones (#1-10) were on line, 20 cm apart, either 30 or 60 cm above the water of the artificial pond. Two were 37 and 72 cm above microphone #8. The microphone output was sampled (12 bit, 500 kHz) on an AviSoft UltrasoundGate. Each file was ususally 3 s in duration.

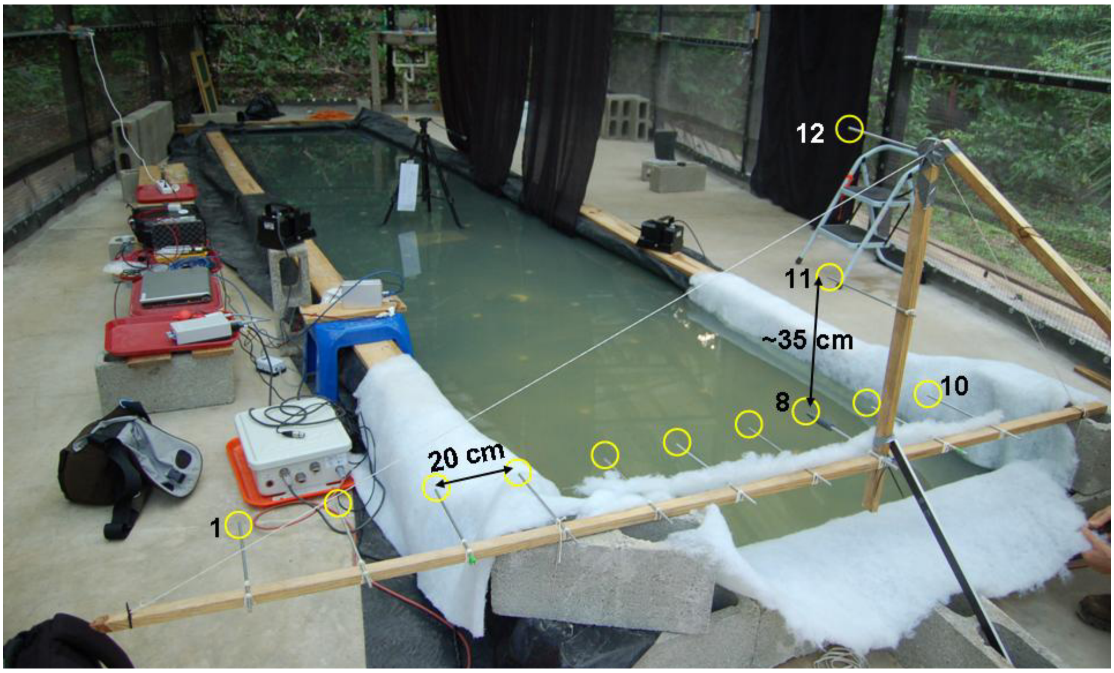


Figure 5. Set-up with microphone array for laboratory recordings of echolocation behavior. The figure shows the “pond” in the flight cage on BCI. The bats were capturing prey on or above the water surface while flying towards an array of 12 microphones, marked with yellow circles.

The echolocation calls were also recorded with a second array of 32 microphones. The flight path and capture behavior of each trial were documented by two different sets of high speed video, one with a single camera (the “Ulm-system”) for details in capture technique and a second (the “Edinburgh-system”) for face and ear-movement at the approach and capture phase. Sound recording systems as well as both video systems had pre-trigger features, with a buffer memory allowing for manual triggering after a bat had passed the array at appropriate distance and direction. A video cam-corder with night shot was used to document overview of the bat behavior.
We recorded pursuit sequences and reconstructed the flight paths based on the time-of-arrival-differences of the echolocation sounds at the microphones in the array (Fig.5). The configuration of the array in the lab allowed for reconstruction of flight paths in three dimensions. We controlled the flight paths determined from the sound recordings by means of the video recordings. The prey was placed at different distances from the array and high speed video cameras, to sample different phases of the pursuit. The bats flew on a relively straight line towards the prey and the array, and veered upwards and around after capture to avoid colliding with the microphones.

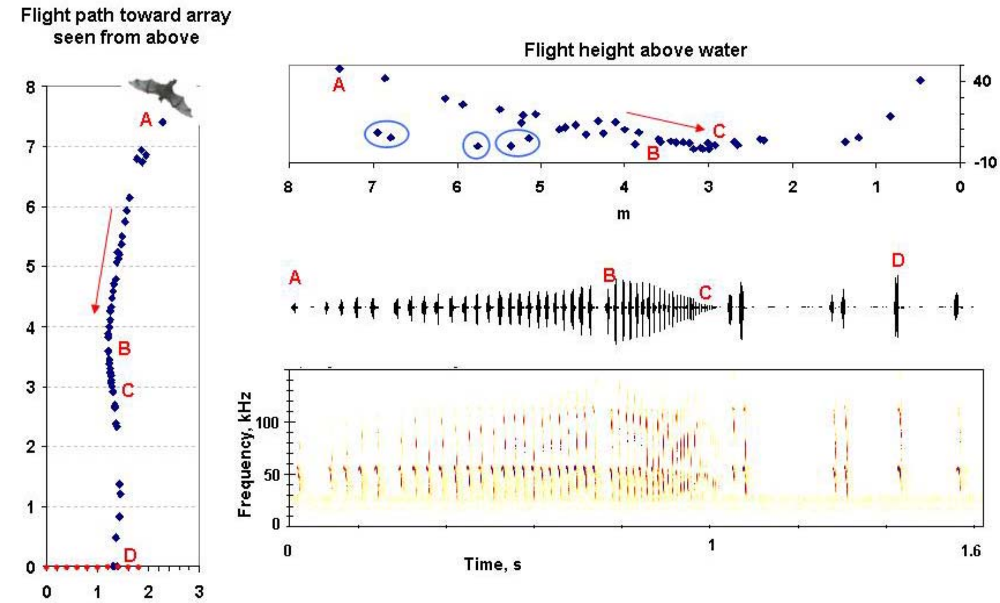
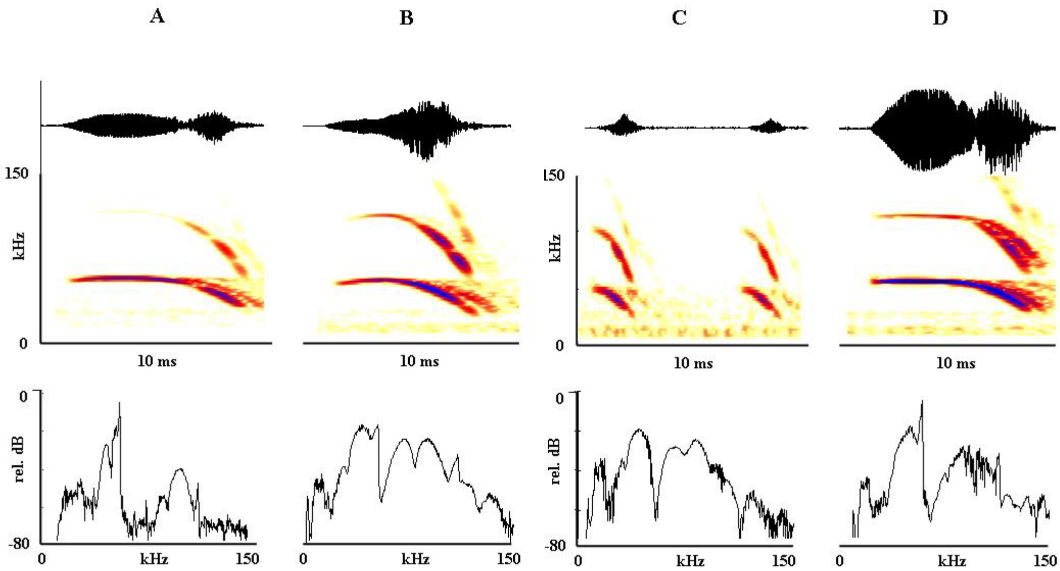


Figure 6. Laboratory recordings of echolocation behavior. The figure shows a flight trajectory from above (left panel) and from the side (upper right), which depicts the flight height. Below the side view is the recording of the calls shown as oscillograms and spectrograms. The side view and the recording are aligned, but only approximately, since flight height is shown as function of distance from the array, and calls as function of time. The calls marked with blue rings in the flight height graph are probably positioned wrongly due to strong reflections of the sounds from the smooth water surface. A, B, C and D denote a search, approach, buzz and post-buzz call, respectively. Prey was taken right after C.

Figure 7. Details of calls A-D from fig. 6 showing typical echolocation calls from search (A), approach (B), terminal phase (C) and post terminal phase (D). The panels show oscillograms, spectrograms and spectra of the echolocation calls from the four phases. The recorded amplitudes are shown to scale and reflect both the decreasing distance to the set-up and the bats decrease in output intensity as it approaches the prey.



N.leporinus' echolocation, flight and capture behavior in the laboratory resembled that observed in the field, but we never recorded as long durations or as high output intensities in the lab as in the field. However, the bandwidths were the same, and the general pattern of changes in acoustic features through a pursuit sequence was the same as in recordings from the wild. This indicates that relations between morphology, mouth- and earmovements and sonar beam shape and beam aim deduced from laboratory measurements will also be valid for natural behavior of *N.leporinus* in the wild. It remains to be shown if *N.leporinus* show the same relation between emitted intensity and sonar beam directionality as demonstrated for *M.daubentonii* where the increased output intensity in the field is linked to the increased directionality, such that in the field the echolocating bat focuses the sound energy in the forward direction, probably by opening the mouth wider.

Conclusions.

The comparison of laboratory and field recordings of *N.leporinus* echolocation calls showed the same typical differences as for *M.daubentonii* with field search calls being of longer duration, louder and perhaps more directional than calls emitted in the lab. We predict that all aerial insectivorous bats hunting for prey in open or semi-open areas will show these typical differences between lab and field recording, which are likely to reflect natural differences between open and cluttered habitats. However, the general pattern of echolocation was quite similar in the lab to that observed in the field, i.e. showing distinct characteristic changes of echolocation call features correlated to the phases of the pursuit sequence. Hence, we conclude that the acoustic behavior of the bats in the lab strongly resembles the behavior in the natural habitat in the field, allowing us to draw biologically relevant conclusions about the performance of the echolocation from our laboratory experiments.

