How far away can female mosquitoes hear the flight tones of their conspecific male-swarm?

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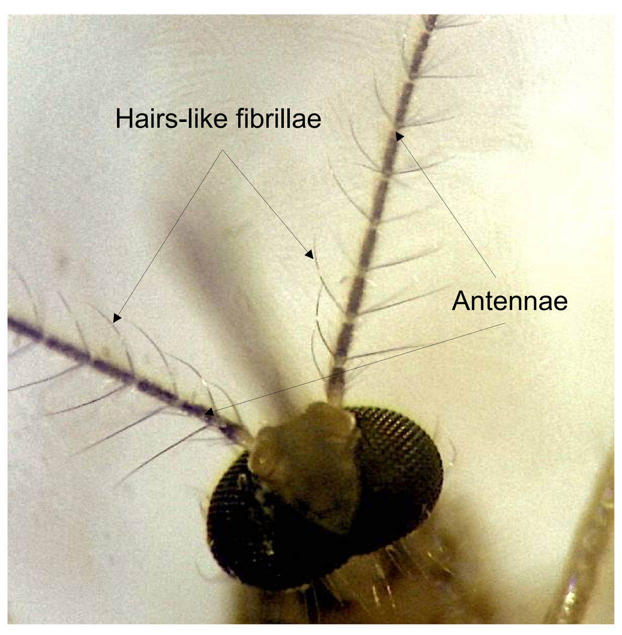
Background

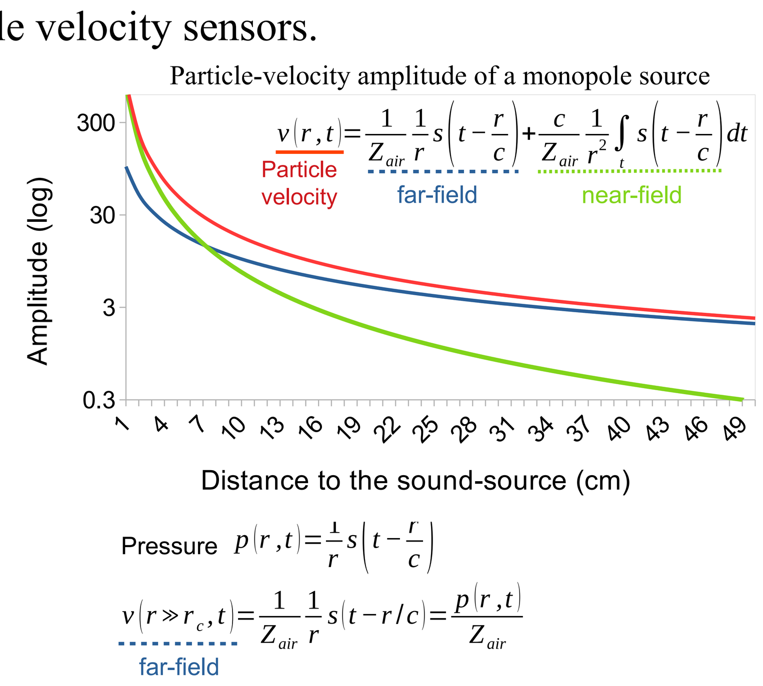
Mosquitoes have the most sensitive hearing of all arthropods, however, this hearing mechanism is based on a particle-velocity sensor, which is optimal only at short distances. Consequently, scientists have assumed that mosquitoes use sound for only very short-range communication. Theoretically, however, a mosquito can hear a sound at any distance, provided it is loud enough. In practice, a single mosquito will struggle to hear another mosquito more than a few centimetres away because the flight tone is not loud enough. However, in the field mosquitoes are exposed to much louder flight tones. For example, males of the malaria mosquito, *Anopheles coluzzii*, can gather by the thousands in station-keeping flight ('mating swarms') for at least 20 minutes at dusk, waiting for females to arrive. We wondered if a free-flying female mosquito could hear the sound of a male swarm from far away if the swarm is large enough, in order to locate and possibly identify a conspecific male-swarm.

Materials & Methods

Sound production and hearing

- Flapping wings produce harmonic sound (300-1000Hz)
- Antennae fibrillae are air-particle velocity sensors.



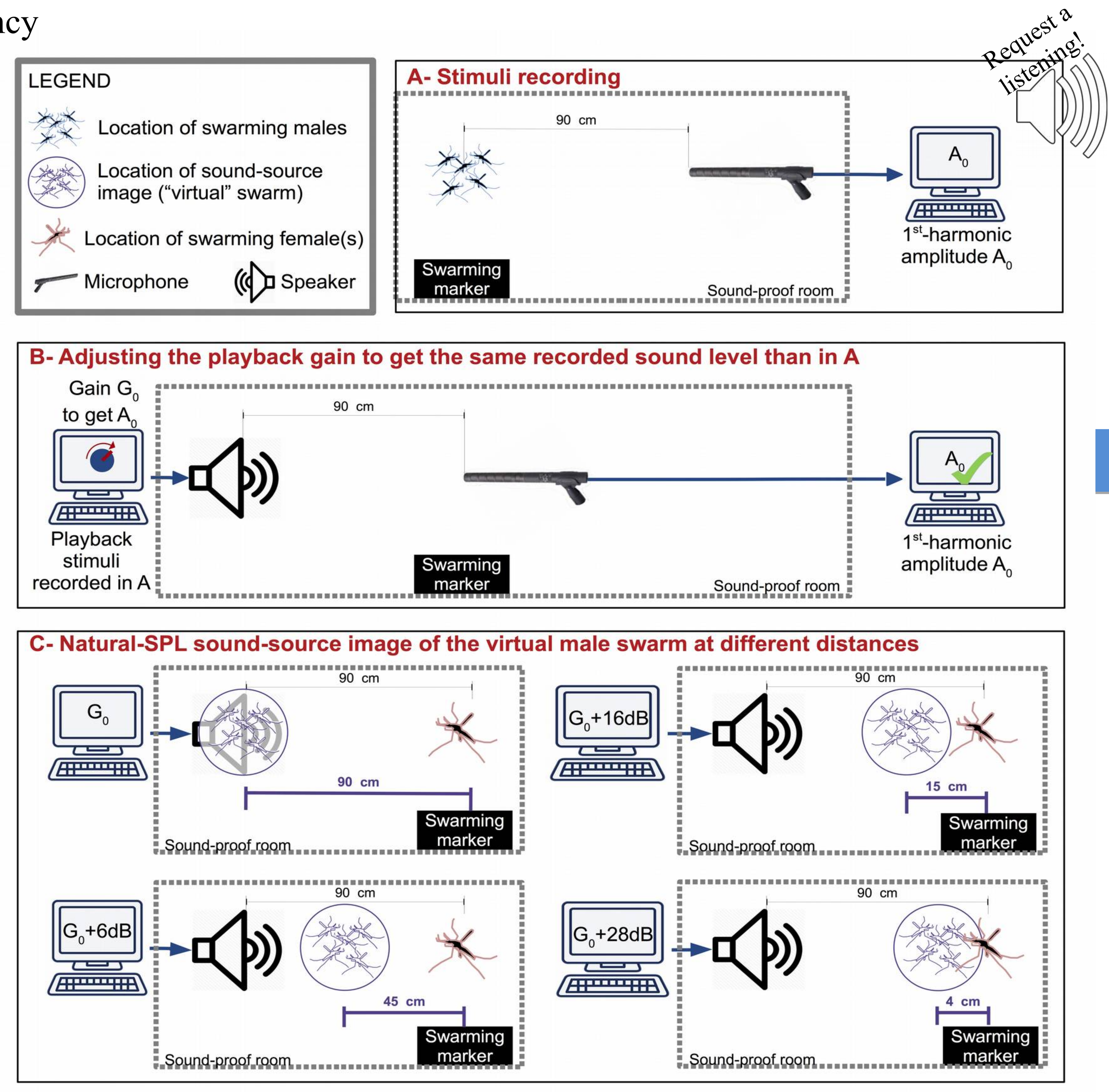


- Sensor best suited for close range hearing

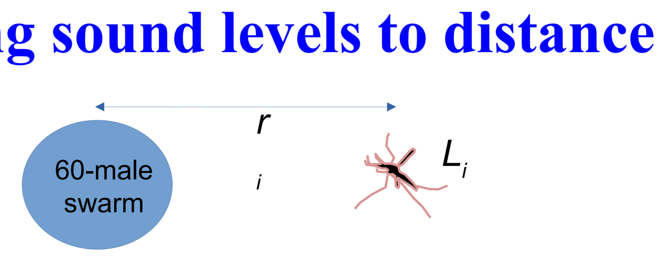
=> Long-range requires powerful swarm-sound

Free-flying female response to male-swarm sound

- Sound of a 60-male swarm recorded and played-back to free-flying females (*An. coluzzii*)
- Female position controlled by her station-keeping behaviour over a ground marker
- Female response monitored by her flight trajectory (Trackit) and her wing-beat frequency

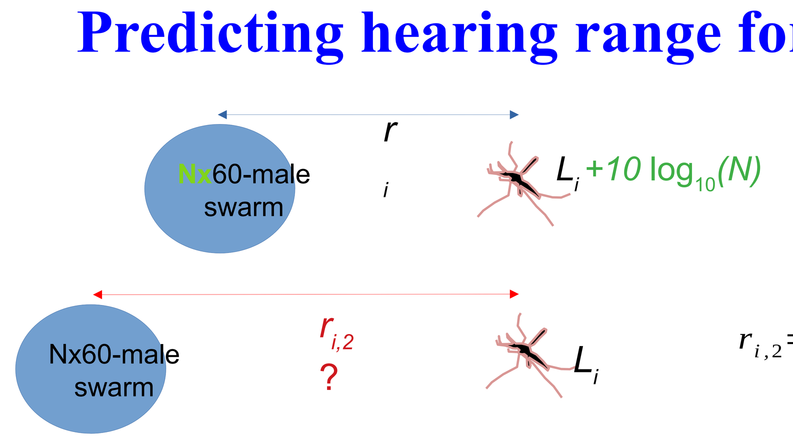


Mapping sound levels to distance to the virtual swarm



$$r_i = r_0 10^{(L_0 - L_i)/20}$$

Predicting hearing range for bigger swarms

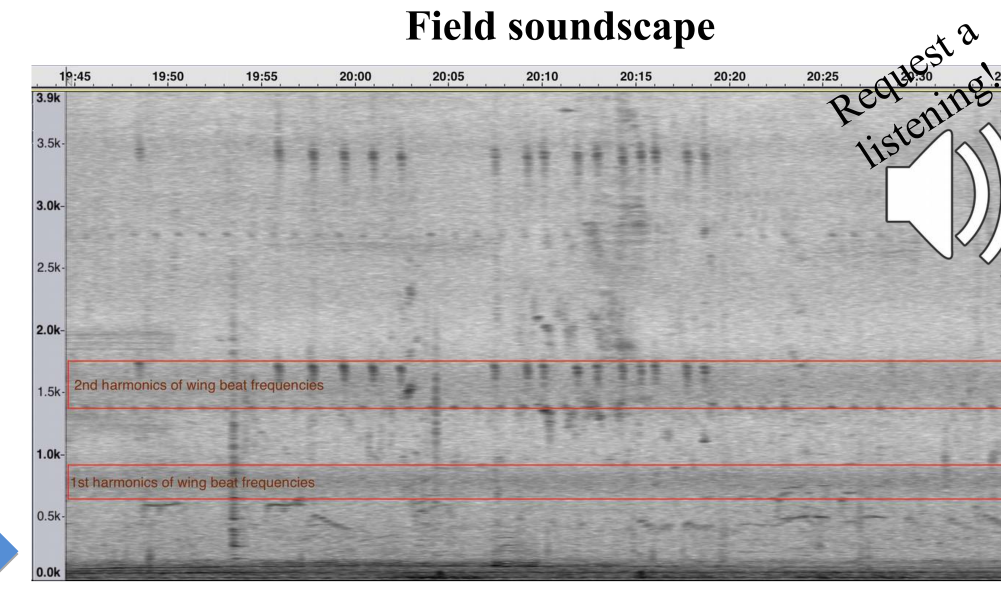


$$r_{i,2} = r_i 10^{(L_i + 10\log_{10}(N) - L_i)/20} = r_i N^{1/2}$$

Results

Field *An. coluzzii* swarms have sound signal-to-noise ratio > 10% 3-m away

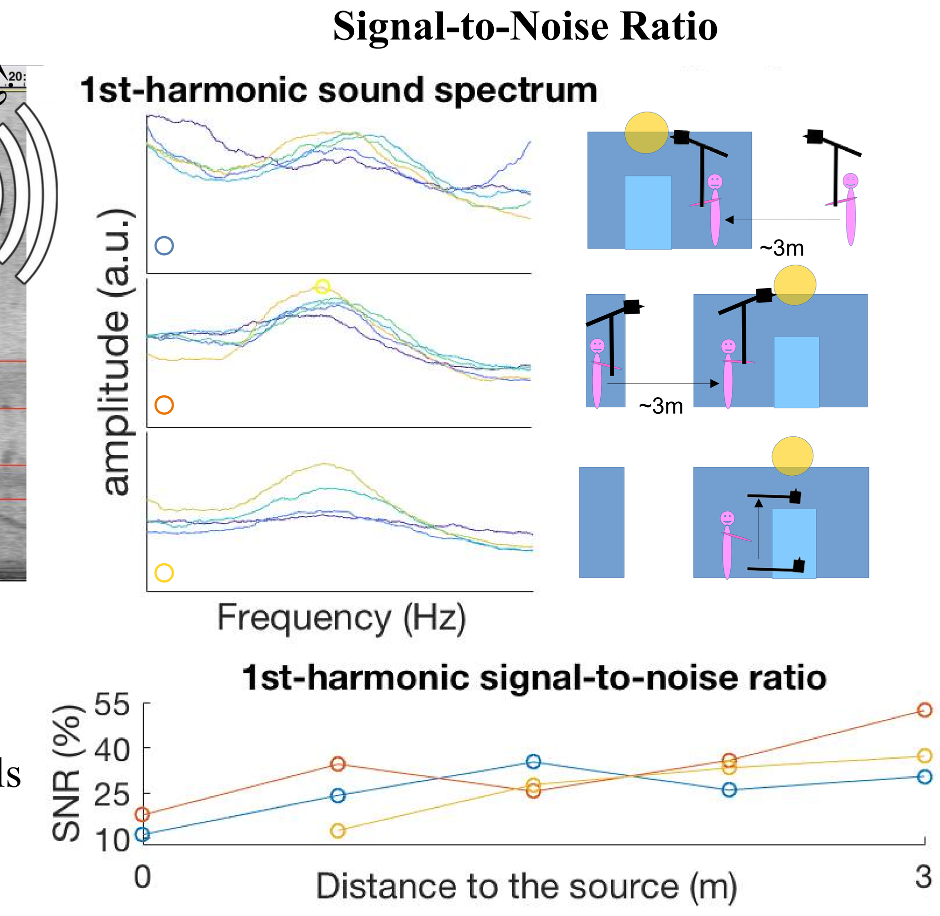
Field soundscape



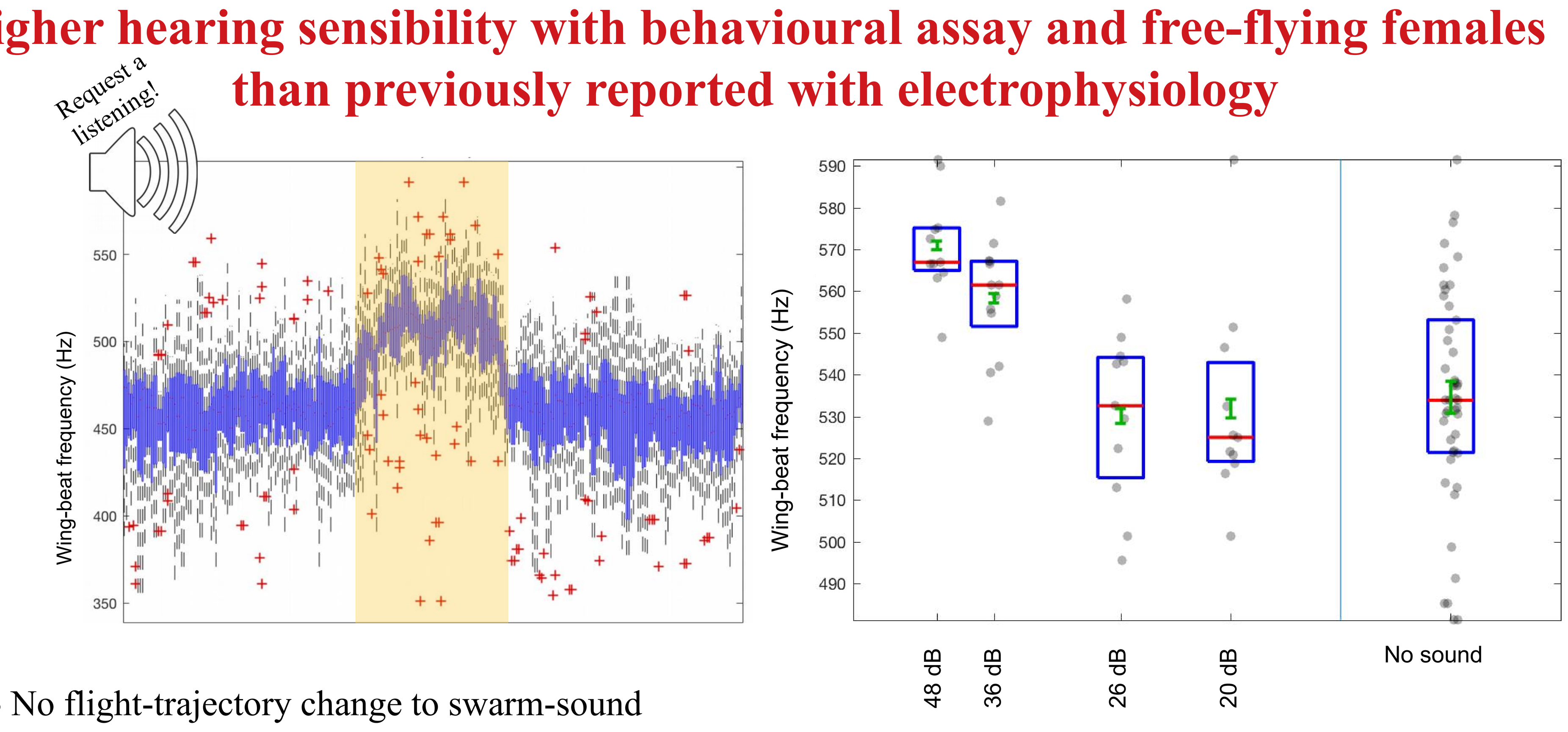
Swarm soundscape in Bama, Burkina Faso (spectrogram over 50s and 0-4kHz)

→ 1st-harmonic does not interfere with other animal calls

Signal-to-Noise Ratio



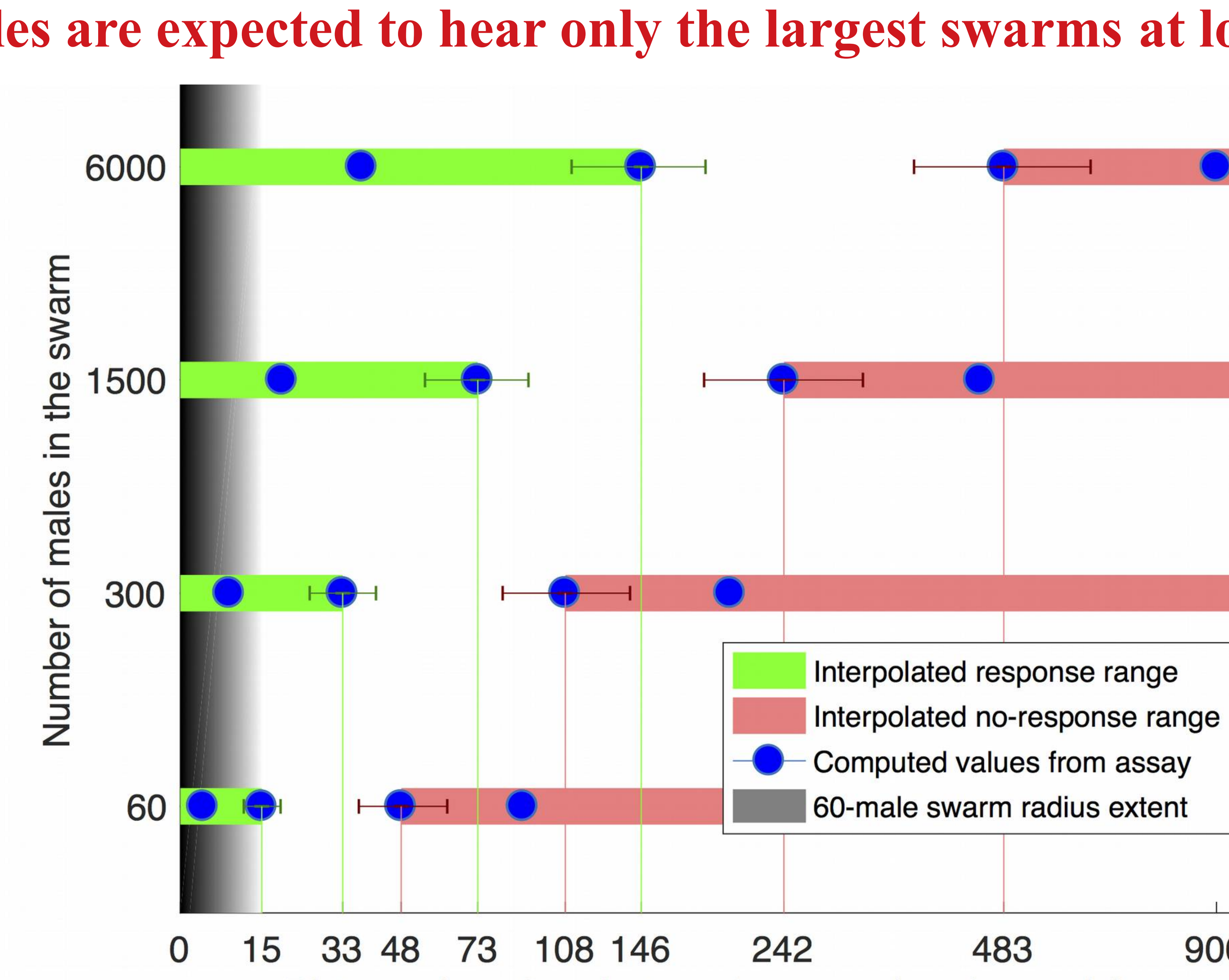
Higher hearing sensibility with behavioural assay and free-flying females than previously reported with electrophysiology



- No flight-trajectory change to swarm-sound
- Response to 32-41 dB is expressed in female as an increase in her wing-beat frequency

→ higher sensibility than previously reported with electrophysiological measurement on tethered females: *An gambiae s.l.* 44-52 dB SPL [Pennetier et al 2010], *Aedes aegypti* 60 dB SPL [Menda et al 2019]

Females are expected to hear only the largest swarms at long-range



Conclusions

- Free-flying females do response to male-swarm sound and their hearing-threshold is equal to or less than **32-41 dB SPL**
- Females **can hear** male-swarm at long-range, but **only if the swarm is large** (e.g. 1,500-male swarm at 0.7-1.4 m away)
- But females **unlikely to use sound to locate swarm** at long range since:
  - * High selection pressure occurs with small swarms which are not loud enough to be heard
  - * Presence of large swarms is correlated with high number proximity (~10m) of swarms (Diabate et al 2011), then it would decrease the difficulty for females to find swarms
- Then why are swarms so loud?
  - * Females **may use the swarm sound to identify whether it is a conspecific swarm** before entering it to avoid being inseminated by other *Anopheles* species
  - * Individuals **males and females rely on high sound levels at short-range** to hear each other and mate

Anofeel Project
JCJC-15-CE35-0001-01 to Olivier Roux

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