Will Neotropical insectivorous bats adapt to climate change? An approach from a physiological standpoint

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Background:

Climate change is altering species composition and their productivity worldwide. Keystone species like insectivorous bats might be at risk, especially in ecosystems like Neotropical pre-montane forests, where changes in weather conditions are expected to be more severe compared to what has been forecasted for lowland habitats. Bats play critical ecological roles; insectivorous bats, in particular, exert control over insect populations on which they prey, thus controlling the abundance of potential pests. Therefore, it is essential to understand how they may respond to the predicted rise in ambient temperature due to the ongoing climate change.

Thermal physiology control animals' ecological success, and thermal tolerance is an important trait that governs the fitness and distribution of organisms. Unfortunately, this trait is largely conserved across lineages1, and environmental temperatures tend to be closer to the upper thermal limit of species that live at lower latitudes (Sunday et al., 2012). The predicted rise in temperature may trigger physiological damage if it surpasses the species' thermal tolerance (Buckley & Huey, 2016). Hence, species' persistence and fitness will depend on their capacity to respond or compensate for environmental changes. Bat responses will be critical to building information for adequate conservation strategies.

We aim to determine the maximum temperature at which vespertilionid bat species maintain basal metabolic rates and gauge their sensitivity to changes in temperature. It has been suggested that, at Neotropical montane forests, species might be less likely to evolve physiological tolerances to increased heat (Bozinovic et al., 2014), reducing the probabilities of adaptation. We used values of the upper thermal tolerances on bats to study the consequences of thermoregulatory constraints and help elucidate the impact of climate change on bat species. Also, we aim to determine intraspecific variability in thermal tolerances among different individuals and differences among sex.

Field site and target species

We collected data at Las Cruces Research Station located in Southern Costa Rica at Coto-Brus county, close to the boundary of the largest protected area in the country (Parque Internacional La Amistad, see Figure 1). The site includes tropical pre-montane and lower montane forests with the frequent presence of clouds (Enquist, 2002). Altitude range from 1200 to 1800 m above sea level, ambient temperature between 15°C at night and 28°C during the day, and relative humidity between 60% and 100% across the year. These ecosystems are crucial for biodiversity conservation due to high species diversity and endemism (Cadena et al., 2012), where bats are not the exception (Chaverri et al., 2016). However, it has been predicted that they may suffer some of the most significant shifts in weather conditions within the country (Karmalkar et al., 2008). We focused on insectivorous bats from the genera *Myotis* (family Vespertilionidae), specifically *M. pilosatibialis* and *M. riparius*.

We used mist-nets to capture bats from 17:30 (before dusk at the study site), when vespertilionid bats start their activities, until 20:00 when bat activity drops. We aged, sexed, and taxonomically identified all individuals, then we fed the bats with mealworm larvae (*Tenebrio molitor*) and provided water *ad libitum*. The last meal was at 23:30 to ensure bats enter a post-absorptive state when we start the experiments.

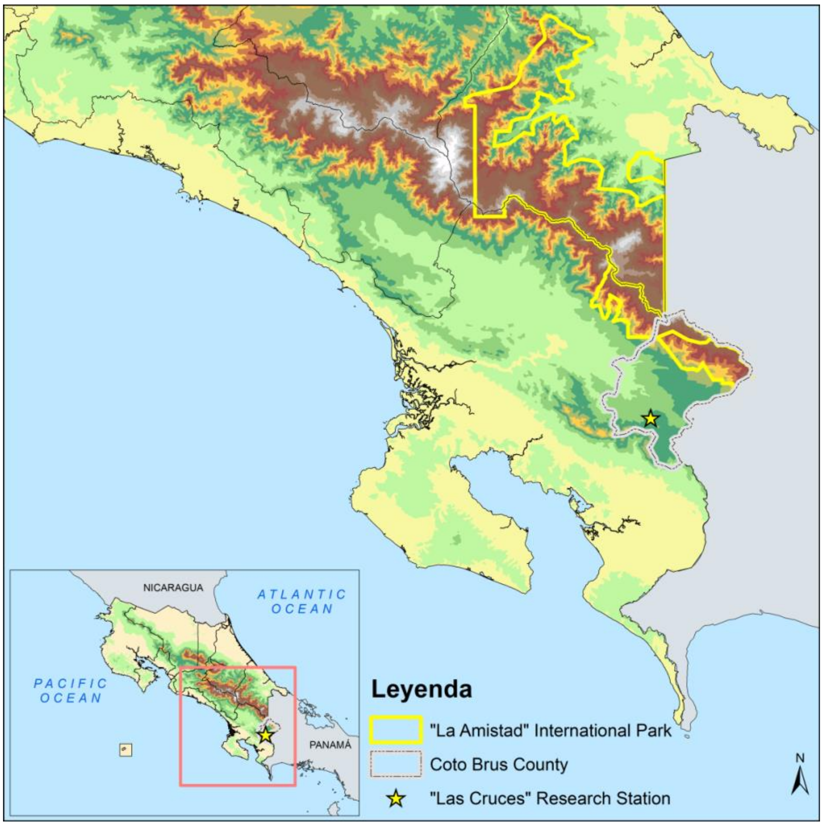

Figure 1: Map showing the location of the study site in Southern Costa Rica and the proximity to the largest conserved area in the country.

Physiological experiments:

We weighed the bats and put them into the corresponding chambers in bath water to begin the experiments with all chambers at 27°C of ambient temperature (Ta). We pumped air (250-270 mL min-1) through a mass flow controller (FB8, Sable Systems International, Las Vegas, NV, USA) into the 0.5 l respirometry chambers. Excurrent air from the chamber and baseline air were subsampled sequentially using a respirometry multiplexer (MUX3-1101-18M, Sable Systems International, Las Vegas, NV, USA). We recorded data of O_2 consumption, CO_2 production, and water vapor pressure (WVP) were recorded directly with the Expedata software via the data acquisition interface

(Sable Systems) and the Field Metabolic System (FMS, Sable Systems), which is a fully-integrated respirometry system optimized for field use. Figure 2 shows a schematic representation of the equipment used during measurements.

We kept the bats at 27°C for one hour and increased the Ta by two °C every hour until we reached 39°C, the maximum temperature at which we measured the bats. We measured bat body temperature (Tb) via PIT tag (BioThermo13, Biomark, Inc.) every five minutes using an antenna (HPR Plus, Biomark) in the insulated chambers. We use the sterile syringe to make a tiny incision under the bat's skin, where we insert the small transponder. We injected the transponders subcutaneously in the mid-dorsal area of the bats (between the skin and muscle). Once the transponder is inserted, we were able to record the core temperature of each individual with no further manipulation.

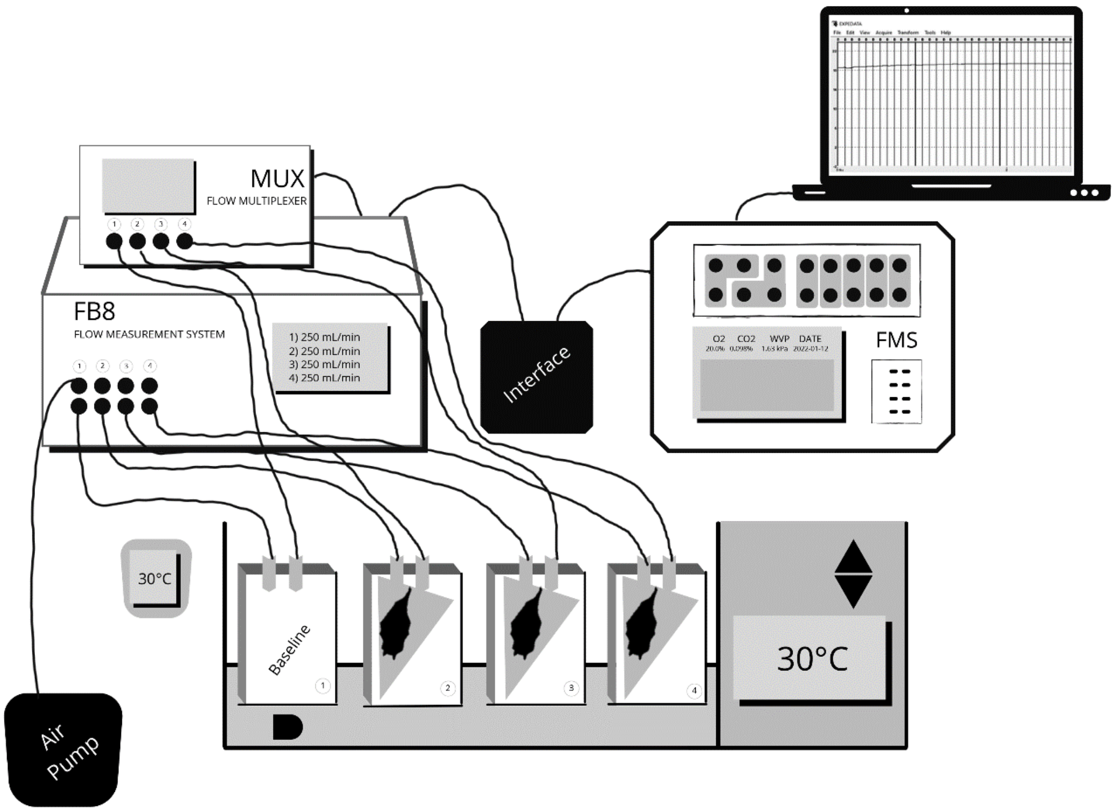

Figure 2: schematic representation of the equipment used and the connections made to carry out the respirometry experiments for the target species.

We recorded data for 33 bats of the target species *M. pilosatibialis* and *M. riparius*. Half of the individuals were males, and the other half were females, which allows us to compare species' responses by sex.

Next steps:

- Analyze data and assess physiological responses of bats to increasing ambient temperature.
- Evaluate the effect of reducing the air relative humidity on species resilience.
- Assess sensitivity to projected increased temperatures due to the ongoing climate change.
- Compare responses between species and between sexes within species.
- Publish results in a peer-reviewed journal
- Share results to a non-academic community and young students by performing oral talks and posters or infographics.

Due to the covid pandemic, fieldwork was postponed. This is why we have not done the outreach with students yet. For now, we are planning to do it in mid-July 2022.

Budget Justification

We used all the budget as it was stated in the proposal. We made slight changes that I specify here:

1) The cost of field materials increased because we decided to use the PIT tags (BioThermo13, Biomark, Inc.) to measure core temperature. This helps to have more accurate data on the bat's body temperature. This also is very helpful to avoid bats becoming stressed because the core temperature is an excellent index to measure animals' heat stress. We used £ 400 initially intended for food and lodging, then completed food and lodging from another source.
2) We also used the Sable Systems equipment instead of ADInstruments to measure respirometry in bats. This equipment is better when working in the field and gathering more accurate data. I needed to pay for a short course (4 days) to learn how to connect and use the equipment and make some calibrations to ensure quality data. We used the budget from the outreach section, specifically "Prepare activities for outreach and train students from at UCR-Golfito," because this will be online, and no funding will be needed.

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