Project Update: May 2023

Objectives:

- To quantify benefits of insectivorous bat guano and insect pest control vis-à-vis conventional fertiliser and pesticide inputs.
- To develop analytical models to assess net benefits in the utilisation of ecosystem services from insectivorous bats, and trade-offs with potential costs to people (e.g., cultural costs, disease risks).
- To derive indicators of "irreplaceability" for insectivorous bats and apply them in conservation planning and community outreach in agroforestry systems.

Progress update (since the previous report)

I conducted intensive overnight acoustic monitoring of bat activity during the mid- and late- rice-paddy seasons in one of my field sites (Uttar Kannada district, Karnataka). Monitoring was done in one organic and one conventionally managed rice-paddy fields. After a year, I am glad to share that I have been able to complete the voluminous, difficult, and time-consuming task of semi-automated bat acoustic data processing, along with the necessary calibration for recording noise errors in the instruments used. I have also been able to successfully conduct plant growth experiments, conduct chemical analyses to test the efficacy of bat guano as fertiliser (reference: my submitted proposal and progress update 1) and literature review for meta-analyses. Below are the detailed updates of the components completed.

a) Bat acoustic data processing.

- In my bat acoustic monitoring, I conducted overnight acoustic recordings using bat ultrasound detectors in two types of paddy fields. The paddy fields differed in their management practices (conventional and organic) and locations (valley and plateau paddy). Two detectors were deployed simultaneously in the two selected fields, for 11.5hours per night for 15 detector-nights each. This together resulted in recordings of about 345 hours (20,700 minutes) across both fields, generating data with total size of ~2 TB.

- Post-fieldwork, in the past months, I supervised each of the 20,700 minutes of data to be able to bring it into a cleaned, noise-corrected, and analysable form (Figure 1). I did this because there are yet no dedicated fully automated software available for Indian bats, to efficiently separate bat calls from non-bat calls and noise, and for call processing and analyses. Although manual checks could not be done away with, I used some support from semi-automated software for increasing the efficiency of bat call detection using convolutional neural networks. I also worked on assessing the recording efficiency of detectors and error rates of classification software (for bat detection in cricket-noise filled soundscapes) by carrying out manual calibration of individual bat calls across devices.

- Despite the technical difficulties and steep learning curve involved in the above, I am glad that this part of my proposed work has been addressed quite well by now.

- Now that this time-consuming process is complete, I am now conducting statistical analyses on these data to quantify the exact contributions of insectivorous bats in controlling insect pests in paddy fields.

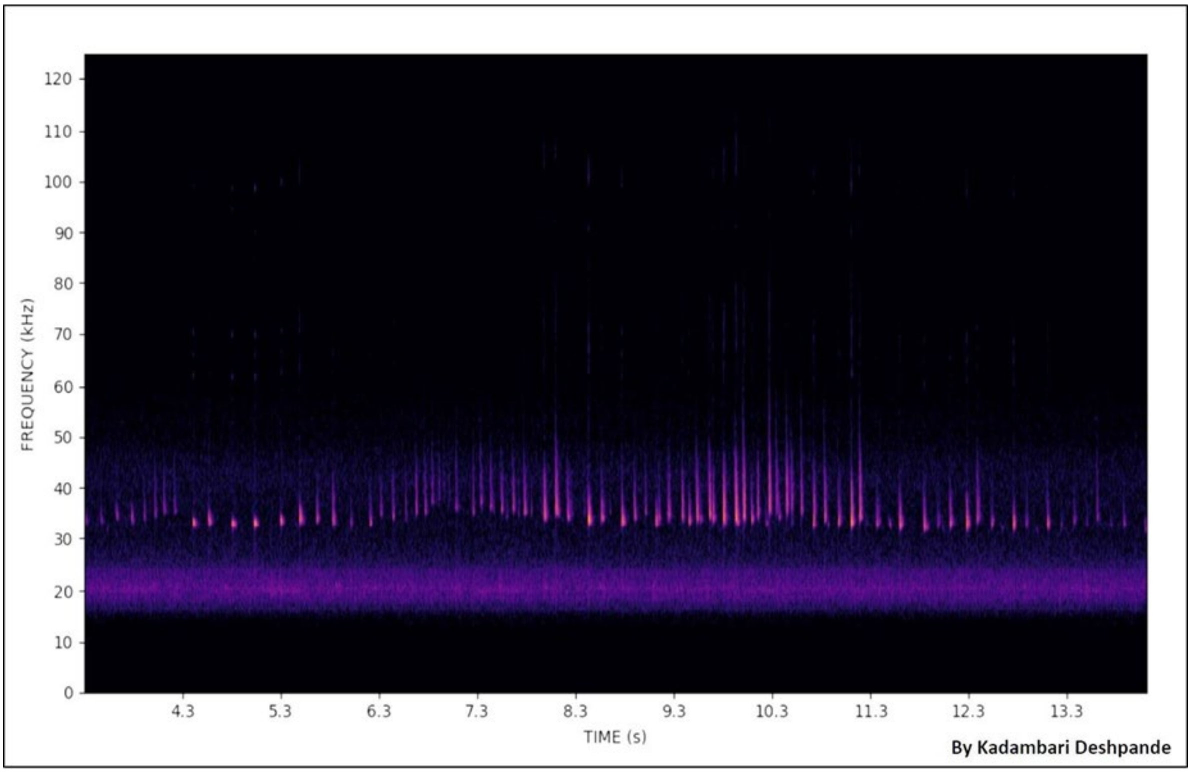

Figure 1. An example of a snapshot of bat activity recorded in rice-paddy field.

- Total bat foraging activity was twice as high in the conventionally managed (with chemical pesticides) paddy field than in the organic field (no pesticide usage). Activity of open-space aerial feeding bats (Emballonuridae, Molossidae, and a few Vespertilionidae) accounted for 29% and 63.5% of total activity, and activity of edge-space aerial feeding bats (most Vespertilionidae) was 70% and 35.5% of total bat activity in the pesticide-managed and organic field respectively. Activity of forest-dwelling narrow-space flutter- detecting (NSFD) bats (Rhinolophidae) was only 0.3% and 1% of total bat activity, with organic fields having higher activity.

- Bat activity was relatively uniform throughout the night in conventional paddy than in organic, with the latter showing three distinct activity peaks: dusk, mid-night, and pre-dawn. Also, bat activity remained similar across seasons in the conventional field. But in the organic field, bat activity sharply increased in the late season.

b) Chemical analysis of bat guano nutrients.

- During my fieldwork in the Western Ghats, I procured bat guano samples from a cave, which local farmers regularly collect for use in agriculture. After navigating a lot of logistical constraints (unavailability of active machines in known labs to analyse nutrient composition, review of chemical analysis methods, and some apprehensions by chemical testing facilities about analysing bat guano) and following all the safety measures as recommended by the IUCN-SSC Bat Specialist Group guidelines (2014), I finally got the chemical analysis of bat guano completed.

- Two forms of guano samples were analysed - 1) “weathered”: bat guano in powder form, and 2) “unweathered”: guano in pellet form. Bat guano was handled with utmost care while wearing masks and gloves during this process, as per the IUCN Guidelines.

- The samples were then outsourced to a lab in Bangalore for testing various parameters, such as pH, electrical conductivity (EC), organic carbon (OC), Nitrogen (N), Phosphorus (P), Potassium (K), Calcium (Ca), Magnesium (Mg), Sulphur (S), Zinc (Zn), Iron (Fe), Cu (Copper), Manganese (Mn), and Boron (B).

- Phosphorus and Potassium concentrations of the unweathered guano sample were higher than in weathered guano. Unweathered guano also had higher concentrations of zinc, calcium, magnesium, sulphur, and manganese, compared to weathered guano. However, weathered guano had higher concentrations of iron, boron, and copper, while also having acidic pH compared to unweathered guano (Figure 2).

- Compared to nutrient contents of the soil, all the parameters (except pH of weathered guano) had higher concentrations, in both samples of bat guano.

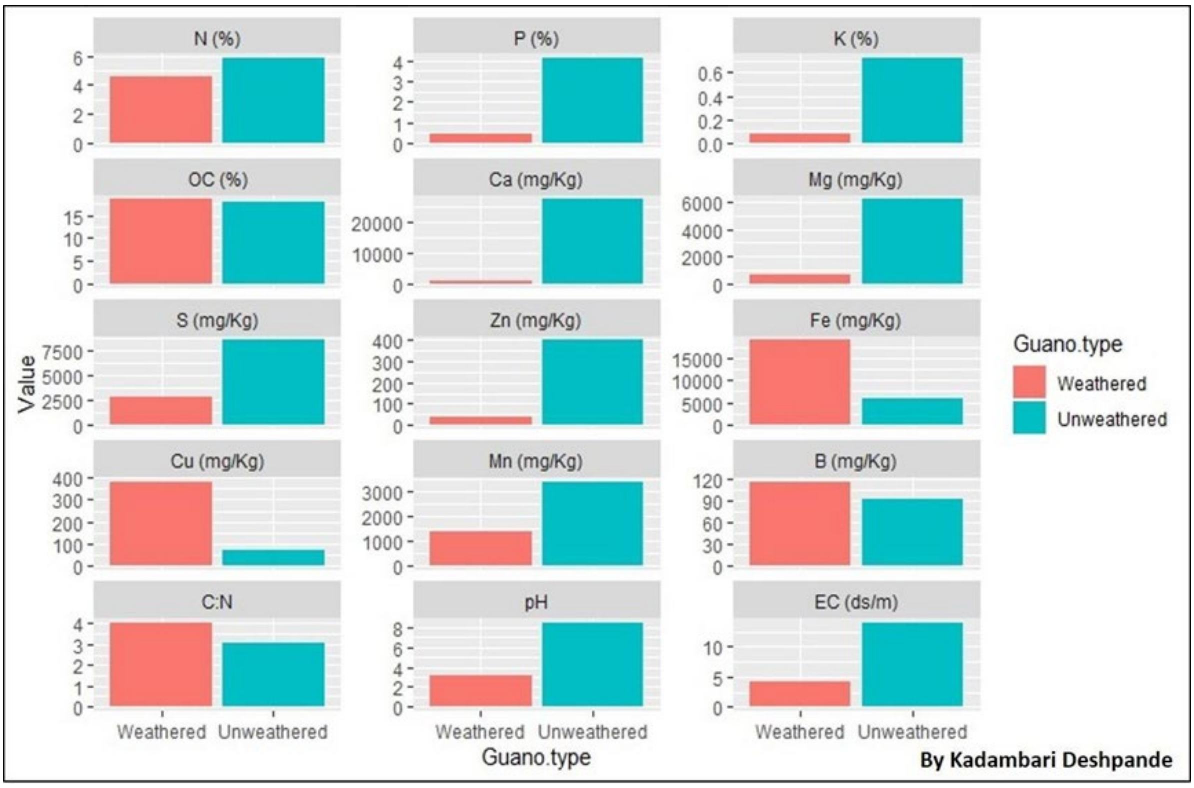

Figure 2. A comparison of chemical properties of weathered and unweathered guano samples.

c) Vegetable growth experiment using bat guano as a fertilizer.

- To assess the effectiveness of bat guano as an agricultural fertiliser, recently I was able to complete plant growth experiments in the field in a control-treatment setup, using chilli as a model crop. The experiment began post-monsoon and after cyclonic and cold conditions in southern India passed.

- The experimental design included four treatments (two types of bat guano as above, standard NPK fertiliser available in the market, and cow dung from nearby village, evaluated against their respective controls (Figure 3).

- For the experiment, concentration of bat guano and other fertilisers were not changed and soil to fertiliser (guano/chemical/organic) ratio was maintained. Guano or fertilisers were added to each treatment replicate every seven days for eight weeks.

- 10 seedlings per four treatments each (10 x 4 = 40 seedlings) and 10 control seedlings per treatment were used as replicates in the experiment. Seedlings were then monitored weekly for plant growth rate and number of flowers and buds.

- Plant growth rates and numbers of flower-buds were highest in the plants with chemical fertiliser treatment, followed by unweathered guano, weathered guano, and cow dung treatments. Differences in plant growth and flower-buds for chemical fertiliser and new guano treatments were significantly different (higher) than for their corresponding controls.

Figure 3: Experimental layout to test the effectiveness of bat guano as a fertilizer.

<u>Current status of the experiment:</u> Fruiting of these saplings will take a few more days. Saplings will then also be monitored for fruits in each type of treatment.

d) Comparisons with other studies and meta-analyses.

As part of this work, I also conducted systematic literature review of studies (>150) from across the globe to identify reasons for bat guano use, what sets guano apart from other fertilisers in terms of its chemical properties and its actual application and utility for different crops. This meta-analysis helped qualify the special value and relevance of bat guano as an ecosystem service. I found that phosphorus release, higher nitrogen, presence of key micronutrients, as well as bacteriological and textural properties of guano were cited as reasons for its effectiveness and utility as fertiliser. However, studies also mentioned that the high variability (both seasonal and spatial) in guano chemical composition was a constraint in guano giving assured results, as compared to chemical fertilisers with exactly known constituents.

Difficulties faced while working on the above components.

- My fieldwork is highly seasonal as it targets the peak production seasons of different crops, being in a tropical region with many bat species that display differential activity patterns.

- The year 2022 witnessed heavy unseasonal rains and cyclonic conditions throughout, and weather conditions were generally unpredictable. Therefore, it was impossible to conduct surveys throughout the seasons, owing to the constraints of logistics and sensitivity of machines.

- The open-field plant growth experiment was also affected, and its execution got delayed due to unpredictable weather conditions.

- Time taken to conduct manual supervision and processing of ~2 TB of bat acoustic data, due to lack of dedicated software for Indian bats, and difficulty in getting computers with rapid processing speeds, was a major constraint.

Future plans (till March 2024).

- I wish to sample the upcoming seasons (post-monsoon), and plan to complete another round of acoustic monitoring of bats in paddy fields, areca, and rubber plantations in the Western Ghats.

- I plan to conduct field surveys and interviews with farmers to understand infestation/herbivory rates of common pests in paddy, areca and rubber plantations.

- I wish to conduct an awareness and outreach activity for the local people/ farmers, which would be ideal to conduct after all the results are obtained.