Final Evaluation Report

Your Details	
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Project Title	The activity patterns and ecosystem services of insectivorous bats in rice fields of Assam
Application ID	27620 – 1
Grant Amount	5180 GBP
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1. Indicate the level of achievement of the project's original objectives and include any relevant comments on factors affecting this.

Objective	Not achieved	Partially achieved	Fully achieved	Comments
Collect morphological, photographical, acoustic, and diet data from insectivorous bats.				We caught and processed 135 individual bats, belonging to ~10 species. Only three species were identifiable based on morphological characteristics. The remaining species will be identified by the forthcoming genetic analysis.
Conduct an exclusion experiment of bats on rice.				This was the first of its kind anywhere in the world, and we found a significant difference in plant health when bats were excluded from the crop.
Collect and analyse trends in temporal activity patterns from passive acoustic recordings of insectivorous bats over rice.				The passive recordings, which amounted to ~4000 hours, showed that bat activity was influenced by insect activity, temperature, and moonlight.

2. Please explain any unforeseen difficulties that arose during the project and how these were tackled.

Working with the combination of bats and rice brought unexpected and unforeseeable difficulties. This was partly because our experiment was the first to exclude bats from rice, so there was limited previous information to go on. For example, one 'unit' of rice is not a single plant, but rather a bundle of anything between one and 10 plants. These are planted by hand in imperfect grids, which adds to the variability in output between and even within plots. In order to make unbiased comparisons, the plots used for the exclusion experiment were not measured by area, but rather by number of plants within. This removed the inconsistencies that would have arisen due to uneven planting and standardised the comparison. In addition, by taking a larger number of plant units per plot (900), differences in the number of plants that went into one 'unit' were averaged out.

Adding to difficulties of working with rice is the sensitivity of this crop to weather and soil conditions. The annual flood which submerges the crop for a short period of time will affect the growth of the crop differently if it keeps different areas of the land submerged for different periods of time. This was the case at one of my sites, where the flood stopped between the control and experimental plots of a single pair, thereby submerging one, and not the other. This resulted in a great difference in growth between the two plots. It so happened that this pair of enclosures were dropped from the analysis for other reasons, but had they been left in, the results might have been significant for reasons other than bats.

Differences in soil quality had similar effects, and simple things like the history of the plot of land, the number of times it is tilled before planting, and the presence or absence of herds of cows grazing in the field before planting begins all contribute to the productivity of the plot. These factors could not be controlled during my study and are the main cause of the excessive variance in the exclusion experiment dataset.

Among other things, I learned that when working with rice one needs extremely high levels of control over the soil quality, the weather, the method of plantation and the strain of rice. In addition, the scale of the experiment needs to be as large as is logistically possible to ensure that the results one gets are statistically significant. Small scale differences due to localised disease spread or wind knocking over rice can and will have a significant effect on the productivity of a plot of rice. If the experimental area is small, then these effects will submerge those that one is trying to detect. Knowing this, future studies can take precautions to limit the strength of unwanted effects, thereby improving their chances of demonstrating the dynamic under consideration.

3. Briefly describe the three most important outcomes of your project.

- The results of my exclusion experiment indicated that while there was no difference in total yield between the experimental and control enclosures, there was a significant difference in plant health.

  The lack of a difference in yield is very likely due to a low number of replicates – our study had six which was reduced to five by the end. Five sets of data would require an extremely large and consistent effect to be statistically significant, which likely resulted in our non-significant result. The measures of plant health were not so limited because we sampled 30 individuals from each plot, and one of these measures was significantly different between the two treatments. This result would strongly suggest that bats are reducing the abundance and/or activity of insect pests of rice, leading to lower levels of damage.

- The passive acoustic dataset collected during this study is one of the largest of its kind in India. The analysis of this dataset indicated that insectivorous bat activity over a rice season was influenced by nightly temperature, moonlight intensity, and, importantly, insect activity. These are supported by studies from around the world that demonstrate bats being more active on warmer nights,

and less active on bright nights (a consequence of greater predation pressure). That bats track insects in rice fields are a dynamic that has been investigated only a handful of times, and never in India, and is highly suggestive of a valuable ecosystem service. This result would also bolster the results of the exclusion experiment.

- On a more fundamental note, this project has obtained data on the acoustic, morphological, and dietary characteristics of several species of insectivorous bats. These data will form the basis of many subsequent studies and empower other ecologist to conduct studies based on acoustic monitoring without the effort of building their own acoustic library. The irrefutable link between bats and pests will come when the diet data has been analysed. This was delayed due to the COVID pandemic closing the labs but is scheduled to commence soon. It is with this diet data that I can identify the species of bats that have the greatest financial value to farmers, and, in time, design protocols for their conservation.

4. What do you consider to be the most significant achievement of this work?

5. Briefly describe the involvement of local communities and how they have benefitted from the project.

This project can be broadly divided into three parts. The first and second, data collection and data analysis are now complete. The third, implementation, will follow.

Thus far, local communities have benefited only insomuch as they have been involved in the construction of my enclosures, sourcing bamboo and renting out plots of land for my experiments. I held many town hall style meetings as well as innumerable conversations about my project and its value to them, but we are only now reaching the point where the project can be translated into practical advice/policy.

Even so, it would be irresponsible of me at this stage to issue a blanket suggestion to conserve bats without first a thorough risk analysis by an epidemiologist. Even before COVID, zoonotic transmission of pathogens from bats to humans, direct or indirect, had resulted in a number of outbreaks, SARS, MERS, and Nipah, being a few examples. The more contact there is between people and bats, the more likely it is for mutation and transmission to occur. This itself is a field that requires greater understanding, and any measure that will result in increased contact between humans and bats must first be analysed for potential risk.

The results of my study strongly suggest a large benefit to farmers in the form of pest control by insectivorous bats. Maximising the value of this service will take interventions to increase the carrying capacity of rice dominated landscape for key bat species that are known to hunt important rice pests. Our to be conducted diet analysis will tell us which bat species are most valuable in this regard. Making agricultural landscapes more habitable to these species will increase their pest

control and decrease crop loss without additional cost to farmers. This would be of great value to the farming communities of the country, but more research is needed before it can translate into a policy or management solution.

6. Are there any plans to continue this work?

I am currently focussed on completing my PhD, after which I fully intend to focus on agroecological questions in India. No decisions have yet been made about the direction of my future research.

7. How do you plan to share the results of your work with others?

Various parts of this work will be disseminated differently. To begin with, basic data such as call libraries and species distribution data will be published online soon. The three routes of inquiry – the activity patterns of insectivorous bats, the diet analysis, and the exclusion experiment – will be published as three separate papers (at least two in 2022). The methods themselves might be published as a stand-alone paper as well. My PhD thesis is also soon to be published. It will contain the two papers mentioned above, as more detail from field that might be relevant to future ecologists.

I have already shared part of my results in the form of a poster at the National Bat Conference (hosted by the Bat Conservation Trust) in 2021. The complete results have also been requested by the District Forest Officers of Nagaon and Tezpur, as well as the District Agricultural officer and the Krishi Vigynayn Kendra. I shall be sending them to these offices when they are published.

8. Timescale: Over what period was the grant used? How does this compare to the anticipated or actual length of the project?

The grant was used between August and December 2019 for the purchase of scientific equipment and to cover the costs of a field season. This was the expected length of the field season, and we collected most of the data we hoped to during this time. The project itself involved 2.5 more years of analysis and writing to produce scientific articles that are now being submitted to journals. The COVID pandemic limited access to the labs, which has delayed the analysis of the diet data, but that is set to resume soon.

9. Budget: Provide a breakdown of budgeted versus actual expenditure and the reasons for any differences. All figures should be in £ sterling, indicating the local exchange rate used. It is important that you retain the management accounts and all paid invoices relating to the project for at least 2 years as these may be required for inspection at our discretion.

Item	Budgeted Amount	Actual Amount	Difference	Comments
Local air fare (Bangalore to Guwahati and back)	280	265	-15	
Permission to set up exclusion experiments.	200	198	-2	
Salary for 1 field assistant for 3 months	550	800*	+250	*A second field assistant was hired for part of the field season. What small funds were left over from the salary and other budget items was used for this.
Salary for workers for the construction of enclosures, public relations assistance.	590	590		
Housing for myself + 1 field assistant for three months	500	506	+6	
Food (and household supplies) for 3 people for 3 months	200	200		
Equipment				
Exclusion nets	450	450		
Ropes	75	75		
Bamboo	95	95		
Mist net	200	200		
Mist net mounting apparatus	20	20		
Lights, gloves and miscellaneous equipment	120	120		
Black light insect trap	50	50		Black light traps were not available for purchase nearby, so this fund was used for miscellaneous equipment, including pheromone lures for the same purpose.
7. Acoustic lure	1704	1700		

Emergency and medical fund				
3) Rabies vaccinations	20	20		
4) Emergency hospitalization	50	20	-30	There were two minor incidents requiring medical attention during the field season.
Contingency fund	80	80		Unexpected travel expenses for myself and my field assistants during the bandh/protests in December 2019.
TOTAL	**5184**	**5389**	**+205**	

10. Looking ahead, what do you feel are the important next steps?

The first of the many potential future steps is publication of the raw data and results of these studies. Even the anecdotal data gathered over the field season – such as presence/absence of certain bat species – is valuable and can be built on by others. One of my challenges when planning this project was the lack of such data. Publishing it will make future research easier. Of great importance is the acoustic call library of bats in Assam. Having this freely available will allow future ecologists to conduct studies based on acoustic monitoring without having to catch the bats, with the bat identification made purely from the call characteristics.

The projects conducted with this grant, and others from my thesis, are the first exploration of the dynamics of bats in rice landscapes and the potential of insectivorous bats to control rice pests. With 60% of India's population dependent on agriculture for their livelihood, investigations into sustainable, resilient methods of pest control, that also protect biodiversity are of great importance. We now know that bats show potential in this area, so future studies must consider their ecology in other agricultural systems, both for their conservation and for the economic value of their ecosystem services.

This must involve investigations into their roosting ecology, habitat preferences, and spatial and temporal patterns in activity set in agricultural landscapes. But alongside this attention must also be given to the virology of bats, particularly those that may interact with humans. While larger bat populations are beneficial to farmers, they may also increase the risk of zoonotic transmission of pathogens. We need to understand these risks if we are to propose measures to increase the carrying capacity of landscapes to bats.

11. Did you use The Rufford Foundation logo in any materials produced in relation to this project? Did the Foundation receive any publicity during the course of your work?

I have used the Rufford logo in a conference paper titled 'Bats track pests and reduce plant damage in rice fields' submitted to the National Bat Conference 2021. The trust has also been acknowledged in two academic articles soon to be published, one still being written, and in my PhD thesis.

12. Please provide a full list of all the members of your team and briefly what was their role in the project.

My team had two full time members, and a host of part time members.

Seemanta Jyoti Baishya worked with me from September 13, 2019, to December 13, 2019. As the only other member of my team to be vaccinate against rabies, Seemanta was the person who helped me in any activity involving handling bats. He was trained to help in the removal of bats from mist nets, as well as to take morphological measurements while I held them. His other duties involved helping me with the raising and lowering of the nets in the exclusion experiment and translating between Assamese and Hindi when we interacted with locals during the course of the project.

Manas Jyoti Talukdar worked with me from 13 October to 13 December. Manas took over from Seemanta in helping me raise the nets of the exclusion experiment in the mornings and took over completely the lowering of the nets in the evenings, while Seemanta and I went to set up mist nets. Manas also joined me during the mist netting of bats and would help check the nets if they were placed far apart.

Nirmala Devi worked with me intermittently throughout my project. She is the sister of my host, and as a member of the village council, was invaluable in organising town hall style meetings where I could explain my project to the local community, as well as providing projection to me and my team during our work at night. She would very often come with us when we went mist netting, and her presence often discouraged harassment. In addition, she organised the locations for me to set up my enclosures and brokered the deals with the respective landowners.

A number (9) of other members of the village were involved in the construction of the exclusion experiment at the start of the field season.

On the academic side, my supervisor, **Rob Whittaker**, and my collaborators, **Uma Ramakrishnan, Orly Razgour**, and **Francois Regal** have been assisted me in the analysis and theoretical advice in preparing the manuscripts for publication.

13. Any other comments?

A by-product of my long stay in Puthimari – the village where I collected my data – was that I also got to become part of the lives of the villagers, and so got to hear their unfiltered view on many things relating to bats and other wildlife. For example,

most farmers know, without any reason as to why, that bats help in controlling rice pests. The same is true for birds, and so part of their pest control involves putting small branching twigs into the mud at various points in the fields. This gives the swallows and other insectivorous birds sites to perch and rest, which I would guess increases the distance to which they would fly and forage. When I spoke to these farmers about my plan to set up bat boxes, they immediately understood what I was talking about because they were already doing the same for the birds. This is in sharp contrast to the other half of the population who believed that we were catching bats to make medicine or to eat them. A frequent request/demand was that we give them the bats after we were done with them.

A trend that has been sweeping Indian villages is the switch from mud and bamboo houses to concrete ones. The village that I stayed in was no exception. With insects abundant, I believe that roosting sites are the limiting factor for bat populations in rural landscapes and this conversion is likely to drastically decrease the carrying capacity of the landscape for bats. Many of the older generation farmers whom I spoke to mentioned that 10 years ago there were far more bats to be seen. This fits in with another fact, which is that my original field site, where the farmers reported bats 'blocking out the moon', had not switched to concrete houses. While I am sure that the report of bat numbers was an exaggeration, I can also believe that if I conducted my exclusion experiment there, the results might have been different.