Final Evaluation Report

Your Details	
Full Name	Carlos Eduardo Restrepo Giraldo
Project Title	Sensory traps in arid environments of Mexico: New insights for bat conservation in a drier future
Application ID	40398-1
Date of this Report	28/03/2025

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
1. Ultrasonic detection and recording			100%	From our partial report of May 2024, we commented that around 40 monitoring points were assessed in the arid landscape of central Mexico between the states of Guanajuato, San Luis Potosí, Jalisco and Aguascalientes, and 37 of them proved worthy for being stablished as permanent monitoring points, since those sustained high levels of bat activity. Out of these, a subset of 20 points were selected based on logistic feasibilities. The ultrasonic detectors were installed near solar panels (less than 10m), water bodies (less than 5m), or vegetation (less than 1m), in a way that in sites in the close range to the solar park, detectors were recording over solar panels and water bodies; in sites with no direct influence of solar parks, the detectors were deployed over vegetation and water bodies also. We collected a total of 2880 hours of ultrasonic recordings divided into four recording seasons, i.e. February-March 2024 (Spring), June 2024 (Summer), September 2024 (Fall), and December 2024 (Winter), from the 20 simultaneous recording points active for three full-night periods (~12 hours), resulting in 240 independent recording nights distributed along 10 control sites, at least 30 km away from this or other solar parks, and 10 sites within the influence area of the only photovoltaic utility-scale facility which

				agreed on participating in this project. This recording effort yielded more than 300000 audio files from which we manually extracted a total of 58400 files with echolocation signals that were used to calculate the general bat relative activity indexes, which estimates the proportion of time the different bat species are present relative to a total amount of recorded minutes. We present here the general activity trends of the whole insectivorous bat community. Activity patters per species will be available upon the completion of the analysis, for which a manuscript is being prepared.
2. Aerial imagery acquisition			100%	Around 6280 hectares of multispectral (red, green, blue and near infrared bands), high resolution (3m x 3m) satellite imagery were acquired through a grant from Planet Labs PBC, within the Education and Research Standard Plan (ID 743204), which provides access to 5000 km² per month for a two-year period. Images were selected based on the date and quality, using images (if available) captured the same week as the ultrasonic recordings from each of the 20 established monitoring points, and with no clouds casting shadows over the land surface. The image corresponding to a single monitoring point (centre) was cropped into a circular 500m-radius buffer. Upon recollection of images for a single season, we set at least 100 georeferenced training points inside each buffer, classifying the predominant land uses and land covers: trees, water, solar panels, buildings and roads, shrubland, cropland, barren. Once the training

				points were established, Google Earth Engine was used to train Random Forests for a supervised cover classification obtaining shapefiles that were processed afterwards with ArcMap 10.5 for extracting the landscape metrics from FragStats Tool. After selecting the most significant landscape metrics (area and edge density), we built Generalized Additive Mixed Models for explaining the general bat activity in function of the landscape metrics of each type of cover.
3. Field experiments		75%		The field experiments were modified to include one additional activity after considering it with the advisors committee: gather empiric data over the solar panels at the park before setting an experimental design away any solar park. This because it was deemed central to how closely bats can be seen interacting with solar panels, this way we could make sure the experiments would have some of the expected bat responses, i.e., bats interacting or flying at low altitudes over solar panels. For this part we conducted several thermoacoustic transects (monitoring simultaneously with thermal cameras and ultrasonic detectors) over all the inner roads of the utility-scale solar facility in two monitoring campaigns (October 2023 and May 2024). These field observations rendered useful information on how active bats could be over solar panels in contrasting seasons, having better thermoacoustic bat detectability in warmer seasons, i.e. more visual and auditive confirmation over solar panels. On the other hand, by late October 2024 the managers of the solar park

				introduced us to Liliana González, chair of Riplast S.A. de C.V. (https://www.riplast.com.mx/), a company specialized in the final disposal of special waste like solar panels. Liliana was eager to collaborate with us and lent 15 solar panels (2m x 1m) for our experimental purposes. Nonetheless, by that time of the year the experiments could not be carried out since we had more frequent tropical storms and colder temperatures; these conditions were not the optimal given the experiments were planned to happen in the warmer months of the year, when bats in the wild would be more motivated to search for any water source. The experiments are scheduled for early May 2025 when high temperatures are expected without any significant storms happening. Having this activity been postponed by the abovementioned reasons, the fuel dedicated for this activity at the end of 2024 was reallocated for completing the acoustic monitoring. The funds for this fieldwork will be provided by the Environmental Sciences Division of IPICYT.
4. Community outreach			100%	From our partial report of May 2024, we commented that by late 2023 we held conversations and engaged in prospective activities with the members of El Salado community (San Luis Potosi), from which Aziel Montoya and Baltazar Montoya played fundamental roles. They helped us with the scouting for the potential monitoring points that needed to be tested for bat activity; throughout this process (25-29 October 2023; 5-12 December 2023) Aziel and Baltazar received formation on bat ecology,

				also we shared our hypothesis on the risks that poses the water scarcity in places like El Salado to wildlife in general, and insectivorous bats in particular. On the other hand, while scouting the potential monitoring points inside and in the influence area of the solar park in El Llano, Aguascalientes, the solar company assigned staff workers that also are part of the local communities, as our field chaperons aiming to gain a first-hand understanding of our study objectives and the goals of this project. From this point on, with every visit to El Llano throughout the acoustic monitoring seasons, the company assigned their staff members of the following communities: Los Sandovales, La Luz, Palo Alto, and El Copetillo. For about three hours of fieldwork during each one of the 17 visits, the staff members would learn about our project, the basics of bat ecology, and why it is important to preserve nature, transforming into a bat enthusiast each one of the staff members at the end of our visits. We are currently working with the IPICYT Public of Relationship Manager to issue official acknowledgements to the 13 staff members who were part of this field/learning activity. In addition, on 16 October 2024 we held a workshop with children from the Nicolás Bravo Elementary School located in El Moquete community at El Llano, Aguascalientes. The three-hour workshop included the participation of three of the solar company staff from the asset management and environmental affairs departments, two teachers from the school, 15

				mothers, and 32 infants from 6 to 12 years old, all between first and sixth grade of elementary school. In this workshop we talked about the wildlife that local communities know from their daily experience, how we can study it and understand it, acknowledging the existence and importance of bats, especially the insectivorous ones as pest controllers, since the region of El Llano has a very prolific list of Dengue cases. The final part of the workshop included an activity led by Gabriela González in which she asked for a volunteer from the public to be transformed into a bat. For that purpose, the audience needed to tell Gabriela the adaptations and essential anatomical features that the volunteer needed to have in order to become a bat. Gaby was progressively adding props to our volunteer like big ears, sunglasses, wings, and so on until the bat was ready. The children were noticeably excited by the activity that enabled them to create their own bat with their own understanding of what a bat is.

2. Describe the three most important outcomes of your project.

a). We identified general activity patters of the insectivorous bat community at local and landscape levels throughout the time, observing that the water bodies locally concentrate greater levels of bat activity followed by vegetation patches, whereas solar panels sustain lesser activity levels. It is remarkable that bat activity does not vary in monitoring points close to water bodies regardless they are located in the influence area of the solar park, or away those areas at control sites. Bat activity also tends to be higher in these control sites regardless the spatial configuration at a local scale (monitoring points near water bodies or vegetation patches). When comparing the monitoring seasons regardless location (near of faraway utility-scale solar facilities) and local spatial configuration, we observed that winter also holds the minimum activity levels, while the activity between the other seasons does not vary in a significant way. Contrary to our hypothesis, autumn is the time of the year when bats spent more time using landscape units with the presence of solar panels, and remarkably this happens after the tropical storms season when water availability is not a limitation on the studied landscape units.

At a landscape level we could observe that the insectivorous bat community tend to decrease its activity at landscape units with increasing solar panel edge density or more meters of solar panel edges per hectare, especially in spring, summer and autumn. In contrast, bats tend to be more active at landscape units with more water edge density (more water edge meters per hectare) particularly in Autumn and Spring seasons, and at sites close to utility-scale solar facilities. Similarly, bat activity increases with bigger water bodies (more hectares) regardless the sites are near or faraway utility-scale solar facilities. The activity over vegetation patches tends to be higher at landscape units with more tree edge density regardless location, and at landscape units with more scrubland edge density, specifically for landscape units near to utility-scale solar facilities. Insectivorous bat activity is higher at landscape units with more cropland hectares, specifically in Summer at control sites (far away from solar utility-scale facilities). Also, at landscape units with more scrubland edge density the bat activity increases when those are located near the utility-scale solar facilities. Regarding land covers that can be associated with open spaces with low resource quality (barren and roads), bat activity decreases with more road edge density in spring and summer seasons, also decreasing with more extended and edge-dense barren areas, specifically at monitoring points located near solar panels. Over landscape units with more extended building areas bats increase their activity levels, especially at Winter and Spring irrespective of the location and local spatial configuration. Nonetheless, at landscape units with more building edge density the bat activity increases only when the units are located near a utility-scale solar facility.

b). All the identified activity patterns are providing hints on context-dependent responses of the bat community to the landscape configuration across different seasons of the year. The most relevant finding is that bats avoid spending time over solar panels most of the seasons, while increasing activity over water bodies in general. Whereas there are also elements in the close rage of solar parks that can enhance the bat activity like having denser edges of water bodies, tree patches, scrublands and buildings. This implies that these landscape elements near to a utility-scale solar facility could act as attractors for the insectivorous bat community in function of their spatial configuration, becoming more important at seasons like autumn and winter after the tropical storm season, when the water bodies become patchier and more widespread which explains the increase in water body edge density at several landscape units. Although our results are not showing any significant effect of solar surfaces in attracting/concentrating bat activity as proposed for a potential sensory trap, the landscape configuration could drive the species to be more active around utility-scale solar facilities at given seasons throughout the year, which in turn can be of importance in the near future if water bodies become less predictable, with reduced size and presence across the arid landscape.

c). With the identified bat activity patterns, we plan to propose a series of measures that can help to reduce the potential impacts of the solar panels on the bat community, since we already know what landscape features can drive the bat activity to increase near utility-scale solar facilities, and there is also the widespread notion that the interaction between the bats and solar panels can be risky for the bats in some cases (collisions, low foraging success, failed hydration attempts), reducing their body condition and fitness. Among the proposed measures based on what we learned from general bat activity are the ones regarding project siting,

since it could be desirable to locate solar panel rows were the bat activity is naturally low, i.e. for future polygon expansions the company should consider the landscape elements that can foster bat activity, like having many buildings or water bodies in the close range. Also, the company could invest some joint efforts on water conservation measures with the farmers for the water bodies located in the croplands surrounding the park. These measures consist in land grading and forming, pond lining with geomembranes, dredging of ponds for preventing high evaporation loss at shallow water bodies, and revegetating with native species for microclimate regulation. This way the water bodies will hold more water for much longer after the tropical storms in autumn, hence the bat activity could be concentrated there after instead of anywhere else closer to the utility-scale solar facility in that season when bat activity seems to be higher over solar panels compared to any other season of the year.

3. Explain any unforeseen difficulties that arose during the project and how these were tackled.

As commented in the partial report, we had significant setbacks that required us to adjust the proposed methodology and consequently the budgeting. While this could hinder the feasibility of the project, we found the way to circumvent such ordeals, and we came up with solutions that even added robustness to the monitoring design. The first of these challenges consisted in changing the institution receiving the funds, since my institution (IPICYT) would impose a heavy management fee exceeding the 10% of the total cost of the project, we decided to work with the NGO Organización Vida Silvestre – OVIS, which charged a 10% management fee. Upon this change we had to adjust the project budget and decided to modify the way in which aerial imagery were to be collected, hence I applied for and was granted with an account from Planet Labs PBC, within the Education and Research Standard Plan (ID 743204), which provides access to 5000 km^2 per month of high resolution images (3m x 3m) for a two-year period. This alone let the drone costs be redirected to cover the management fee from OVIS and other required items.

The second important challenge we faced was the ulterior negative of the 75% of the four solar park managers that agreed on granting us access to their premises for conducting the study. Only the managers of Solem Solar Park agreed on collaborating with us without the restrictions that the other parks were imposing, like censoring the information resulting from this research, or even taking legal action against the researchers. This implied the use of an alternative approach to the proposed experimental design of the monitoring points. Fortunately, Solem is divided into two solar parks, Solem I & Solem II, generating 150MW and 140MW respectively; this allowed us to rethink the extent of the buffers of each monitoring point, so we reduced the radius of the buffers from 2km to 500m.

Consequently, the number of monitoring points was increased to have a more representative sampling of the overall bat activity around the solar park and control sites. In addition, the water bodies proposed to be monitored inside each 2km-radius buffer were scarce in the vicinity of Solem I & Solem II; most of them were entirely dry when we visited the sites located with old aerial images. Only few water bodies remained; being this the case for almost all the proposed control sites at Venado, Charcas, Estación Catorce and la Mesilla, we opted for exploring additional sites with more permanent water bodies at El Salado, Palma de la Cruz, Cañada del

Lobo, Mexquitic de Carmona, and Santa María del Río in San Luis Potosí state, and at San Pedro in Guanajuato state.
This also contributed to the modification of the monitoring methodology: now we were placing the ultrasonic detector in the edge of the water, or a vegetation patch, or a row of solar panels, and this would constitute the centre of the new 500m-radius buffer. In this sense, now we were monitoring 5 points with solar panels and 5 points with water bodies inside or very near Solem I & II simultaneously, and 5 points with water bodies simultaneously with 5 points on vegetation patches in the control sites, more than 30km away from any solar park.
Originally, the proposed monitoring intensity was of 5 nights per buffer, over four buffers inside solar parks, and four in control sites. Considering the monitoring of maximum two buffers at a time depending on the number of available ultrasonic detectors, this would total approximately 40 monitoring nights per season. As a result of the increment of monitoring points, we had to decrease the total time of recording to 3 nights per monitoring point, to obtain manageable data volumes. These 20 points monitored simultaneously for a given season along 3 full nights, resulted in 60 monitoring nights per season. This way we gained spatial and temporal resolution when adjusting to the available monitoring points.
Other relevant challenge has to do with the limited co-funding and unpredictable fund availability by IPICYT. Since 2024 was the year of the presidential election in Mexico, the federal fund expenditure (IPICYT funds) was cut down and limited in the second and third quarter of the year for certain activities carried out at federal institutions, like fieldtrips and other related expenses like the acquisition of miscellaneous material. This adjustment was done acquiring more cost-effective options for the thermal cameras, the spring-scale Pesolas and the calliper Vernier, to compensate for the increase of the budget devoted to field trip related costs, like meals, lodging, petrol, and other hardware and supplies for mounting the experimental set. Whenever the cofunding was not available at the moment of a purchase, the costs were covered by Rufford funds, taking care of covering further expenses with IPICYT funds to balance out the account between the two cofunders; these expenses were mostly represented by food, lodging, and tolls.
Lastly, few days after we collected the recording from summer season the tropical storms became more frequent making it very difficult to carry out the field experiments planned to happen in August 2024. For this reason, we opted for rescheduling all the experimental activities of the project for May 2025 when higher temperatures are expected without any significant storms happening. Currently we are looking at thermoacoustic monitoring data gathered in October 2023 and May 2024 inside the solar park as part of the exercises done for developing a new active monitoring technique, based on detecting bats at flight with their thermal signature and then identifying them with the ultrasonic recording. This enables us to understand how close bats tend to fly and be detected over solar panels and will help in refine the experimental setup showing us what to expect in an experiment recreating a section of a solar park in a remote area of the landscape without any significant influence of utility-scale solar facilities.

4. Describe the involvement of local communities and how they have benefitted from the project.

Throughout the development of this project several people from the local communities were involved at different levels: exploring new monitoring sites for establishing permanent recording points; installing, servicing and uninstalling

ultrasonic recorders while taking a crash course on bat ecology in the field; attending a communal workshop in the local elementary school for learning about local wildlife and bats in preparation for the Latin American and Caribbean Bat Week (24-31 October 2024). These activities helped us to gain insights on the people´s perception on bats. On most cases when we were about to begin with one of the abovementioned activities, we asked to our collaborators what they think about bats, being more frequent the notions based on myths and misconceptions. Nonetheless while the activity was carried out and all the questions they had could be answered, we noticed a change in their attitude towards bats, now considered as allied species in their vicinity, since they benefit farmers and keep mosquito-borne diseases at bay through pest suppression for instance. Interestingly, the workshop with the children taught us that the younger generations have less biased notions on the wildlife inhabiting their surroundings and are eager to have more immersive experiences with the wildlife like seeing an alive bat specimen, unlike the adults who were a little scared of that idea. In addition, the work done with the local community members who are part of the solar company staff and the company itself was fundamental to share some simple but effective conservation actions that can adopted to enhance the local habitats for the wildlife. For instance, the company had the initiative to develop a Burrowing owl nest restoration program for which they asked our technical opinions on some aspects about the ecology of the species. Likewise, the company is eager to learn about the results we are reporting here and the concomitant suggestions on what measures should be taken. Upon the completion of species-specific acoustic analysis for having better details on the responses of each species, we will arrange a results divulgation workshop with the solar company, being confident they will embrace the results of this project as an advance in their conservation efforts intended to offset the impact of operating a utility-scale solar facility. We are currently working with the IPICYT Public of Relationship Manager to issue official acknowledgements to the 13 staff members of the solar park who were part of this learning experience in the field, designating them as *Bat Ambassadors*, since now they possess the knowledge to answer a common question about bats in their own communities, helping to reinforce a better perception of bats on people.

5. Are there any plans to continue this work?

I intend to apply for a Second Small Grant since there are still fundamental notions to be outlined, mainly regarding the seasonality of the water bodies determined by irregular precipitations as experienced in the current project, and how this change on water bodies extension and structure across the arid landscapes could further modify the bats activity patterns. Moreover, the Nicolás Bravo school board and the solar park´s environmental official are willing to collaborate with us in future environmental education events, intended to give a more immersive experience to the children who could observe actual free flying bat species using our equipment of thermal imaging and ultrasonic detection.

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

We are currently preparing two manuscripts; the first is a theoretical one describing the potential evolutionary traps that could affect bat communities, and the second one explains the variation of temporal activity patterns of insectivorous bats in arid

landscapes with the presence of photovoltaic utility-scale installations and diminishing presence of water bodies.

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

First, we need to complete the bat species identification so we can re-run the additive models to understand the species-specific response of the bats to arid landscape changes. Furthermore, we need to share with the solar park and environmental entities our findings regarding the importance of certain landscape elements and how we can manage them to have a specific outcome regarding wildlife responses; especially regarding the water bodies that are located in the croplands surrounding the utility-scale solar facility. We feel that it is imperative that local communities, farmers and the solar company work together to restitute valuable habitats for bats in order to offer safer options in the same landscape portion where solar parks are operating.

8. 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?

Up to the date of redaction of this report I've portrayed the logo of The Rufford Foundation in three of the six dissertations with my advisors committee, which happens every six months as part of the evaluation process in my grad school. Also, in August 2024 I presented a conference with the partial results of this project at the IV Latin America and Caribbean Bat Congress – COLAM, in which The Rufford Foundation logo was portrayed in the acknowledgements and funding section of the conference. Lastly, in October 2024, we presented at the Nicolás Bravo Elementary School the workshop "Meeting my nocturnal neighbours" within the celebration of the Latin American Bat Week 2024, in which The Rufford Foundation logo was portrayed as sponsor of the event.

9. Provide a full list of all the members of your team and their role in the project.

Biol. Gabriela González Olimón: one of the main duties of Gabriela was assisting me in the field with the prospection of the monitoring points, installation and maintenance of the ultrasonic detectors and the capture and identification of the bat species that we needed to record for building our echolocation signal reference library. We shared countless hours in the road and in the field, and I'm sure without her help, all this data would have been harder to get.
Dr. Leticia Cab Sulub: Leticia helped me with the extraction of the landscape metrics of all the buffers of the monitoring points and other spatial analysis performed with Google Engine. The expertise of Leticia helped me in understanding the importance of having a good classification on land cover and land uses and prompted me to do my best in the training point acquisition process in the field, so the classification was the most accurate possible, and the resulting models associating landscape metrics to bat activity patterns were as fit as possible.
Dr. Michael Smotherman, Dr. Felipe Barragán, Dr. Bruce Robertson: Michael and Bruce had a significant input in this first part of the research given they helped me in conceptualizing the idea and guided me towards the use of better and simpler methods and refining the experimental design. Dr. Felipe contributed also to rethinking the experimental design after our first prospections of monitoring sites,

when we realized that finding water bodies with the current climate in our study sites was more difficult than I anticipated. In this spirit, Felipe was always eager to explore new sites and was fundamental for talking with the landowners for gaining access to some of the currently used monitoring points.

10. Any other comments?

We would like to extend our sincerest apologies for the delay in the submission of this final report, since there were contingencies that we were unable to foresee back in September 2024 when I asked for the extension of the submission deadline for November 2024. After collecting and processing the autumn season data we ran the models for explaining bat activity in function of the landscape features, we noticed that the data points pertaining to winter season control sites (El Salado monitoring points) were adding more variance to our results than expected, and this was product of having different control sites for this season compared to the rest of the seasons, where the control sites were located at Mexquitic de Carmona, Palma de La Cruz, Cañada del Lobo, Santa María del Río and San José. In this sense the advisors committee suggested gathering winter data in December 2024, hoping to reduce the noise caused by comparing data from different control sites. Consequently, my intention was to present more curated information with more controlled sources of variation; to do so I had to spend around two additional months to process the new acoustic data and run the satellite image classification and landscape metrics measurements. In addition, I had to coordinate several working sessions with the OVIS financial team to compile all the expenditure reports that I issued to them along the project duration, resulting in a time-consuming process that took a couple of weeks to complete. Finally, it also took a couple of weeks to complete this final report, aiming to present in a practical way all the technical and scientific aspects of the project, providing a clear and succinct view of how this project was managed.