Final Evaluation Report

We ask all grant recipients to complete a project evaluation that helps us to gauge the success of your project. This must be sent in **MS Word and not PDF format**. We understand that projects often do not follow the predicted course but knowledge of your experiences is valuable to us and others who may be undertaking similar work – remember that negative experiences are just as valuable as positive ones if they help others to learn from them.

Please DO NOT fill in and submit this form until the project has been completed.

Complete the form in English. Note that the information may be edited before posting on our website.

Please email this report to jane@rufford.org.

Your Details	
Full Name	Cristina Rueda Uribe
Project Title	Ecological connectivity and seasonal habitat use: understanding hummingbird altitudinal movement to guide conservation of high Andean ecosystems in Colombia
Application ID	36476-1
Date of this Report	10 January 2026

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 tracking data for high-Andean hummingbird species			X	In total we have attached transmitters to 17 individual hummingbirds, three species of paramo and high-Andean forest ecosystems: Sparkling Violetear (*Colibri coruscans*), Bronze-tailed Thornbill (*Chalcostigma heteropogon*), and Great Sapphirewing (*Pterophanes cyanopterus*). Capture rates of hummingbirds in these high mountain ecosystems are low, so we were only able to attach 17, rather than the planned 25, during our time in the field. We did this by setting up an automated radio telemetry system (ARTS) over an area of approximately 2 km^2, at 3,200 m above sea level. The ARTS grid has now also been used to generate movement data of other key bird species. Radio transmitters give a signal every 5 seconds, therefore millions of data points have been collected, giving unique insight into these species' movement ecology. Despite their importance as pollinators in these highly valuable ecosystems, these species of high-Andean hummingbirds have not been tracked before in the wild. This data has revealed high flexibility in

				individual movement behaviors across different vegetation types. It will be further analyzed in different projects, and the ARTS grid will continue to be used to generate movement data for key species. We used Cellular Tracking Technologies LifeTag and PowerTag radio transmitters. LifeTags are powered by solar panels and therefore do not have limited battery life, they work when there is solar radiation, while PowerTags use a battery. Although it can run out approximately 1 to 2 months after deployment, they also give a signal during nighttime.
Collect genetic data			X	169 blood samples were collected from 16 hummingbird species, of which four were selected to extract DNA and then sequence with nextRAD. This generated thousands of SNP data for 95 individuals from four hummingbird species: Glowing Puffleg (*Eriocnemis vestita*), Coppery-bellied Puffleg (*Eriocnemis cupreoventris*), Tyrian Metaltail (*Metallura tyrianthina*), and Blue-throated Starfrontlet (*Coeligena helianthea*). Genetic data was analyzed to explore population structure in the region and landscape resistance to dispersal.
Collect data on plant-hummingbird interactions			X	By identifying pollen grains collected from captured hummingbirds (176 individuals from 13 species), we identified 162 plant species that are visited by 13 different hummingbird species in the region. These plant-hummingbird interactions vary according to the

				time of the year, as well as amount and structure of habitat surrounding sampled sites.
Identify how changes in management practices may alter connectivity		X		Sampling plant-hummingbird interactions and hummingbird genetic structure across a region with different management practices allowed us to infer how these are influencing hummingbird connectivity and their role as pollinators. We found that outside protected areas heterozygosity is generally decreased, and plant-hummingbird interaction networks are less specialized. We plan on continuing sampling to cover variation across years, and collect more genetic samples of rare species to have enough statistical power in population structure analyses.
Extend an ecological and evolutionary modelling platform, to include seasonal movement phases.	X			In this complex and understudied system, more data must be collected to parametrize models. Seasonal movement phases are still not clear, due to high individual-level variability and changes in climatic conditions across years. The project will continue in the coming years to reach this goal.
Understand how movement can be impeded by land use and climate change		X		Our data on hummingbird movement, population genetics, and interactions with plants have already shed light on how land use change can impede movement through the conversion of suitable habitat. We have not yet included climate projections to simulate how plant-hummingbird interactions can change in the future, but this remains a key objective of our project.

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

a) Collected key data on movement patterns and strategies that enable connectivity analyses, using an automated radio telemetry grid that is now being used by Chingaza National Natural Park to track other small animals in the high Andes.

Figure 1. Photographs of three tracked hummingbird species with radio transmitters: Sparkling violetear (*Colibri coruscans*, top left), Great Sapphirewing (*Pterophanes cyanopterus*, top right), and Bronze-tailed Thornbill (*Chalcostigma heteropogon*, bottom). Photos by Manuela Lozano.

b). Calculated population structure and landscape resistance for four hummingbird species with next-generation sequencing, demonstrating species-specific differences in barriers to dispersal under different land uses and management practices. In addition, our data on plant-hummingbird networks show that hummingbird pollination interactions change with habitat amount and structure.

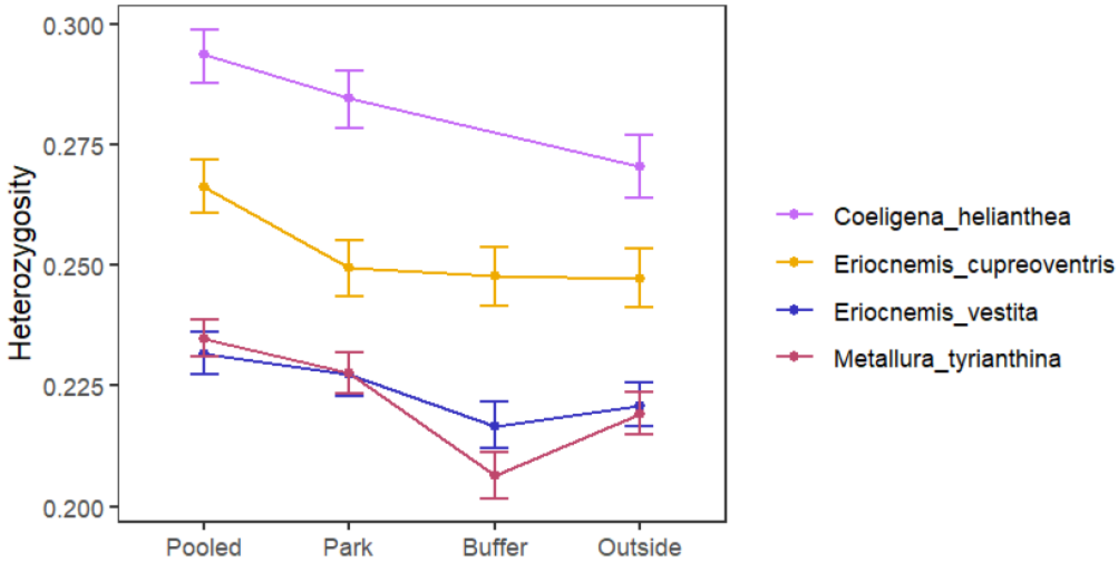

Figure 2. Heterozygosity (H_T) calculated for four high-Andean hummingbird species, pooled for all individuals, and distinguishing individuals sampled inside Chingaza National Natural Park, its buffer zones, and in areas outside in the agricultural and urban matrix. Lines connect points by species colored according to the legend, and error bars indicate 95% confidence intervals by bootstrapping with 999 iterations.

c). Constructed the foundation for management and conservation practices focused on the restoration of habitats for pollinators, through active involvement of eight privately-owned nature reserves and one large protected area, Chingaza National Natural Park. Reserve owners and the park's research team not only participated in project planning, data collection and analyses, but are also now incorporating collected information into their management plans and continue to collect data on plant-hummingbird interactions and pollinator movement.

Figure 3. Park rangers participating in data collection (top, photo by Luisa Díaz), set up of ARTS grid in Chingaza National Park and training workshop with rangers and local resesarchers (middle, photo by Juan Manuel Carvajalino), collaboration with nature reserves for habitat restoration (bottom, photo by Mauricio Restrepo).

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

As any ecology field project, there were many challenges. The major changes to the initial plans that are worth mentioning here include difficulties related to the lack of prior information about our focal ecosystems and species, and technical issues. Very large knowledge gaps about even basic occurrence, demography and biotic interactions of high-Andean species was a challenge to plan efficient field outings and start parametrizing complex connectivity models. However, we were able to collect data and have contributed to start filling those large knowledge gaps with our research. In terms of animal telemetry, using GPS tags as initially proposed was not viable, since these were too heavy for our focal species. To solve this, we used radio transmitters and set up an automated grid for fine-scale tracking.

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

Local communities and regional stakeholders were actively involved in the project and have derived tangible scientific, technical, and educational benefits.

At Chingaza National Natural Park, the project strengthened institutional capacity through the installation of an automated radio-telemetry grid. While this infrastructure was established to generate fine-scale movement data for the focal hummingbird species, it represents a long-term asset that can be applied to other high-Andean taxa of conservation interest. Importantly, all data generated through this system have been shared with park authorities, providing a robust empirical basis to inform adaptive management, monitoring programs, and future conservation planning within the protected area.

In addition, eight private and community-managed nature reserves benefited directly from project outputs aimed at improving landscape connectivity. Restoration have been guided by integrative analyses combining plant–hummingbird interaction networks, reconstructed from pollen samples, and complemented from information of hummingbird population genetic structure. This approach allowed reserves to prioritize habitat restoration and management strategies that enhance functional connectivity and pollination processes across the landscape.

The project also placed strong emphasis on capacity building through the active involvement of biology and ecology students from local universities. Students participated extensively in fieldwork, data analysis, and scientific writing, gaining hands-on training in contemporary ecological and evolutionary methods. Two students developed and completed their undergraduate theses within the framework of the project, contributing original research while building professional skills and strengthening local scientific capacity.

Park rangers were continuously trained by accompanying all field outings and participating in all planning and technical meetings. In addition, we organised a workshop in April 2023 with 10 attendees to specifically train park rangers in using automated radio telemetry systems.

5. Are there any plans to continue this work?

Yes. The project has generated large datasets that are still under active processing and analysis, ensuring continued scientific output beyond the original project timeframe. In addition, it established infrastructure for tracking small animals in the high Andes, which will remain operational and continue to produce movement data for a wide range of species.

The project has also initiated and consolidated research networks at both regional and international levels. These collaborations remain active and are focused on advancing the study of landscape connectivity, particularly for species with key ecological functions such as pollinators. Together, these elements provide a strong foundation for sustained research, monitoring, and the development of future conservation initiatives.

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

The project has been shared with different audiences through scientific articles, academic theses, conferences, workshops and media publications as listed below:

Scientific articles

- Rueda-Uribe, C., Sargent, A. J., Echeverry-Galvis, M. A., Camargo-Martínez, P. A., Capellini, I., Lancaster, L. T., Rico-Guevara, A. & Travis, J. M. J. 2024. Tracking small animals in complex landscapes: a comparison of localisation workflows for automated radio telemetry systems. *Ecology and Evolution*, 14(10), e70405.
- Rueda-Uribe, C., Camargo-Martínez, P. A., Espitia, J., Lozano-Rocha, M., Ríos, J. P., Echeverry-Galvis, M. Á., Lancaster, L. T., Capellini, I., Travis, J. M. J. & Rico-Guevara, A. 2026. Movement strategies of neotropical nectarivorous birds: insights from high-Andean hummingbirds and flowerpiercers. *Biotropica*, *58*(1), e70132.
- Rueda-Uribe, C., Lozano-Rocha, M., Ríos, J. P., Espitia, J., Camargo-Martínez, P. A.,
- González-Arango, C., Orejuela, C., Lancaster, L. T., Capellini, I., Ochoa-Quintero, J. M., Rico-Guevara, A., Travis, J. M. J., & Echeverry-Galvis, M. A. (In revision). Multilayer networks show seasonal dynamics and vulnerability of hummingbird pollination to habitat fragmentation.
- Rueda-Uribe, C., Lozano-Rocha, M., Espitia, J., Ríos, J. P., Camargo-Martínez, P. A.,
- Caballero, S., Echeverry-Galvis, M. A., Rico-Guevara, A., Capellini, I., Travis, J. M. J.,
- Layton, K. S. K. & Lancaster, L. (In preparation). Comparative population structure of four high-Andean hummingbirds across a heterogeneous landscape.

Academic theses

- Rueda-Uribe, C. 2025. Hummingbird movement in tropical mountains: multiscale patterns and ecological consequences. Doctoral thesis. University of Aberdeen. https://abdn.primo.exlibrisgroup.com/permalink/44ABE_INST/1jd70l9/alma9918569899305941
- Lozano-Rocha, M. 2023. Colibríes y plantas, una exploración de sus interacciones a través del gradiente de uso en siete sitios en el Parque Nacional Natural Chingaza y zonas aledañas hacia el noroccidente del área protegida. Undergraduate thesis. Pontificia Universidad Javeriana.

Conferences

- Rueda-Uribe, C. 2024. Invited Plenary Speaker: Altitudinal Movement in Tropical Mountains. Movement Ecology Annual Meeting of the British Ecological Society. Southampton, England.

- Rueda-Uribe, C. 2024. Novel Uses of Old Technologies: Pollinator Movement in Tropical Mountains. 38th Meeting for the Scandinavian Association for Pollination Ecology. Hardanger, Norway.

- Rueda-Uribe, C. 2023. Using and sharing big data: opportunities in tropical mountain ecosystems. Science Summit at 78th United Nations General Assembly - SSUNGA. New York, United States.

- Rueda-Uribe, C. 2024. Plant-hummingbird interactions in time and space: implications for landscape management in high mountain ecosystems of the Andes. Student Conference on Conservation Science. Department of Zoology, University of Cambridge. Cambridge, England.

- Rueda-Uribe, C. 2023. Novel uses of old technologies: a radio telemetry automated system to infer hummingbird movement in tropical mountains. QUADRAT Annual
- Science Meeting, Queen's University Belfast. Belfast, Northern Ireland.

- Rueda-Uribe, C. 2023. Rastreando a polinizadores emplumados: patrones de movimiento de colibríes y sus implicaciones para la conectividad ecológica. Universidad Nacional de Colombia.

Workshops

- Studying pollinator movement at multiple spatial scales. March, 2023. CAMINOS workshop on Pollination in high-mountain ecosystems of the Andes. Guasca, Colombia. 26 attendees: International university professors, MSc and PhD students.

- Using automated radio telemetry systems to track small animals. April, 2023. Parques Nacionales Naturales de Colombia, Parque Nacional Natural Chingaza. 10 attendees: park rangers, Colombian university professors and PhD students.

Figure 4. Workshops on pollination ecology in the high Andes (top) and the use of automated radio telemetry for animal tracking (bottom).

Media

- Forbes Science
- Parques Nacionales Naturales
- University of Aberdeen News

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

Future next steps include continuing the analysis of existing datasets, expanding the use of the established tracking infrastructure to additional species, and integrating movement, genetic, and interaction data into applied ecological connectivity modelling. Also, we will continue to strengthen long-term collaborations with protected areas, nature reserves, and local institutions. This will be essential to translate scientific results into management actions, while continued training of students and early-career researchers will help sustain regional research capacity and impact.

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?

The logo was used in all conference presentations communicating the results of this project. Additionally, the Foundation was acknowledged in published scientific articles and Cristina's completed doctoral thesis.

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

Main team:

Cristina Rueda-Uribe, PhD. Previously student at University of Aberdeen, Aberdeen, Scotland, now postdoctoral researcher at University of Copenhagen, Copenhagen, Denmark: project lead.

Pedro Camargo: local ornithologist and environmental leader, employee of National Natural Parks Colombia in Chingaza. Link with research team of the protected area, main contact in organizing field outings, managing ARTS grid, and logistical support.

Juan Camilo Bonilla: researcher of National Natural Parks Colombia in Chingaza. Main contact with the research section of the protected area, strategic vision of how the project will benefit the region.

María Ángela Echeverry-Chavis, PhD.: Professor and director of MSc in Use and Conservation of Biodiversity at Pontificia Universidad Javeriana, Bogotá, Colombia. Scientific supervision and local logistics.

Alejandro Rico-Guevara, PhD.: Assistant professor and Curator of Ornithology at the University of Washington, Seattle, United States. Scientific supervision and local logistics.

Justin M. J. Travis, PhD. Professor at University of Aberdeen, Aberdeen, Scotland. Scientific supervision.

Isabella Capellini, PhD. Senior lecturer at Queen's University Belfast, Belfast, Northern Ireland. Scientific supervision.

Lesley Lancaster, PhD. Senior lecturer at University of Aberdeen, Aberdeen, Scotland. Scientific supervision.

Kara Layton, PhD. Assistant professor at University of Toronto Mississauga, Toronto, Canada. Scientific supervision.

Student field assistants: Manuela Lozano, Juan Pablo Ríos, Jonathan Espitia, Sarah Chaves, Angie Rodríguez, Daniela Garzón, Daniel Botiva.

Other scientific collaborators: Nicolás Skillings (Researcher, Pontificia Universidad Javeriana), Catalina González (Professor, Universidad de los Andes), Catalina Orejuela (Researcher, Universidad de los Andes), Juan Manuel Ochoa (Researcher, Instituto de Investigaciones Alexander von Humboldt), Susana Caballero (Professor, Universidad de los Andes).

Private reserve owners: Mauricio Restrepo, María Fernanda Gómez, Luis Guillermo Linares, Martha Alcira Díaz, Clara Alméciga, Fundación Natura (Carlos Castillo), Jorge Martínez, Museo Quinta de Bolívar (María Ortíz).

10. Any other comments?

None.

ANNEX – Financial Report

[Intentionally removed]