

Final Evaluation Report

Your Details	
Full Name	Diego Ellis Soto
Project Title	Combining unmanned aerial vehicles with biotelemetry to identify and protect nesting sites of Galapagos giant tortoises
Application ID	24251
Date of this Report	October 2nd 2022

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
Testing the efficacy of the female tortoise nesting algorithm				We were able to successfully show the effectiveness of our algorithm for Galapagos giant tortoises during field campaigns in 2018 and 2019. Another field campaign based on external funding is expected in 2023. There has been interest in this nesting algorithm by the University of Southern Illinois working on reproductive ecology of Galapagos giant tortoise. Thus, this initial small grant in 2018, continues to have a long-lasting impact in the conservation and reproductive ecology of giant tortoises.
Testing the efficacy of using unmanned aerial vehicles to identify female tortoises nesting behaviour				We were unable to fly the purchased drone Matrice 100 model on the Galapagos study sites as the lithium batteries of this drone exceeded the allowed limit of the airline. However, we were able to obtain movement information and exact coordinates of nesting sites of tagged tortoises through jointly analysing GPS and accelerometer data by walking on food and downloading data. Since the inception of this project there have been a number of private companies attempting to track animals remotely using unmanned aerial vehicles with mixed success requiring large amounts of financial resources.
Testing the efficacy of using unmanned aerial vehicles to identify tortoise nests				Through additional external funding, we were able to purchase a smaller drone, the Mavic 2 Dual Enterprise, in 2019. With this drone we were able to identify not only nesting sites in visual and thermal images, but also created a geospatial layer that indicates nesting sites of Galapagos giant tortoises in Santa Cruz across an elevation gradient.

Finding and protecting tortoise nests and informing the Galapagos National Park				We were able to identify multiple tortoise nests by using our algorithm, thus protecting tortoise nests in near real time! Further, we assisted in the protection of nests that we encountered by chance as well as providing critical on the ground information for the sight of tortoise nest predators (goats, feral pig marks on the soil, fire ants presence, etc.) and inform park rangers as we encountered them.
Scientific communication of these results both to the local community and international scientific community				We worked closely with local youth through our collaboration with Ecology Project International and a local high school called Tomas de Berlanga. This included going to the field to radio track and find GPS tagged tortoises and download their data. Following up, data analysis and visualisation with the same high school students took place at their school (using Google Earth in order to make a map). At the end of the day, students had to present and describe tortoise ecology and interpret the movement patterns of the tortoises they had found on their last excursion, further honing their scientific communication skills.
Publishing in scientific journal				We were able to publish on the behaviour and activity patterns of male and female Galapagos giant tortoises (this uses the same signature of the nesting algorithm, the accelerometer signature of the tracking device attached on tagged tortoises). This has been published as a book chapter on Galapagos. The activity patterns of adult giant tortoises are based on the same accelerometer and GPS combination that is used to detect nesting behaviour of tortoises. We have not been able to publish results of the nesting algorithm yet. I provide an extensive list of publications and public talks which were supported by this grant below.
Quantification of nesting characteristics				We extensively measured clutch size, egg size and internal temperature of several giant tortoise nests obtaining critical information on giant tortoise reproductive ecology in the wild. This contributed to

				the understanding of the most unknown stage of life of giant tortoises; their early years also known as 'the lost years' of giant tortoises. This represents a critical contribution to conservation of giant tortoises.
Working alongside and Galapagos national park rangers				<p>We worked alongside Galapagos National Park rangers in protecting nesting sites and protected many critically endangered giant tortoise nests of both <i>Chelonoidis porteri</i> and <i>Chelonoidis donfaustoi</i>. In addition, I wrote a series of field guides translated from English to Spanish. These include best practices for programming hand help GPS with waypoints, how to download and upload data from a handheld GPS (i.e., when verifying the potential GPS points of fresh nests identified by the algorithm), how to customise, set up and program e-obs GPS devices with accelerometers that are attached on giant tortoises to study their movement, and finally another guide on how to best download such data. I also provided information on best practices for uploading animal movement data onto a database (Movebank.org) which allowed me to stay involved in this project during the COVID-19 pandemic. In addition, I published a guide on how to best run the nesting algorithm and store points in a handheld GPS to then go find and validate the algorithm with potential fresh nesting sites and protect these tortoise nests.</p> <p>Importantly, I also helped in capacity building of local colleagues working at the Charles Darwin Foundation providing an analysis refresher on using Google Earth, the use of pivot tables to obtain summary information out of a data set using Excel for data management.</p>

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

I believe that the most important outcomes of this project were to:

a). Showcase the feasibility and utility of the nesting identification algorithm. It is hard to describe the excitement of the first nest identified from the nesting algorithm, as you walk towards a GPS location on your handheld GPS device to find fresh earth piled up in a slight concave shape to what is a nest of one of the most endangered and iconic species on earth!

b). Second, our educational campaign was very successful having reached dozens of local youths and teaching them various aspect of giant tortoise ecology.

c). Third, I believe that the capacity building of local practitioners, field biologists and scientists further improved research capacity in the global south.

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

This project had several unforeseen difficulties, ranging from legal permits on international flight regulations, up to the delay of funds transfer, a global pandemic, and personal health problems (cancer). Additional challenges included me starting a PhD in the fall of 2018 which, while honing my scientific skills, also imposed a time constraint on this project. I am proud in retrospective of having finished this Rufford project and even go beyond the initial proposed work by obtaining additional funding and performing additional field campaigns to protect tortoise nests and refine the created nesting algorithm and even being able to go to the Galapagos again in 2023 to continue this work, among other research aspects of conservation of giant tortoises.

Delayed funding meant that I had to travel to the Galapagos in 2018 without purchasing and bringing the drone in time. For the field campaign in 2019, rapidly changing international flight regulations on the maximum size of lithium batteries did not allow me to transport the Matrice 100 to the Galapagos. In addition, exploratory test flights in New Haven of the Matrice 100 in 2019, revealed potential difficulties with winds when transporting larger material that would likely be hanging and that is fragile, such as a handheld base station to download GPS data.

However, through obtaining additional external funding for conserving giant tortoises and nests, I was able to purchase a smaller drone whose lithium batteries where within the allowed travel limit (Matrice 2 Dual Enterprise) and was able to fly and complete several of the proposed objectives. The COVID-19 pandemic in 2020 and further health complications in 2021 did not allow me finalise and wrap up this project with 'boots on the ground', however as indicated in the amounts of public talks, books written, and scientific article, I was able to write and analyse several of the information collected in this grant, and participate in professional development and additional research which cemented my interest in contributing to conservation in the Galapagos Island and furthered my professional career and interests. Despite the presented challenges, we were able to quickly adapt and were able to protect nesting sites of critically endangered Galapagos giant tortoises of the species *Chelonoidis porteri* and *Chelonoidis donfaustoi*.

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

One of the strengths of this project has been the strong involvement of local communities across organisational levels – from management to science and monitoring, up to local youth.

At the management level, I was able to provide multiple talks and hands-on training to staff from the Galapagos National Park, and local conservation non-profits such as the Charles Darwin Foundation. The Galapagos National Park repeatedly expressed excitement and interest in our work on conserving giant tortoise nests in Santa Cruz Island and provided support in the form of rangers. Thus, I am proud to say it has truly been a two-way collaboration and our working relationships are good. As described above, other deliverables for management and monitoring staff included more detailed information on the nesting sites of giant tortoises, capacity building in the form of creating maps in google earth, use of pivot tables in excel, instructions on how to upload GPS coordinates on handheld GPS, translation of several guides of technical equipment related to animal tracking GPS technology and upload of data into global databases of animal movement, allowing international scientists such as myself to participate in research in near real time in the Galapagos despite not being physically there. At the educational level, many participating local youths benefitted through exposure of hands-on science. In addition, a published book chapter further included a native Galapagos youth who became a co-author of this publication, and she obtained mentorship from me during this progress and is currently a biology graduate from Newcastle University! I strongly believe that the strong involvement of local communities in this project highlights the trust and community building of this research in the Galapagos and myself for the last several years. I consider this to be an integral part of every conservation project I am a part of, particularly as an early career conservationist from a small country in the Global South (Uruguay). Finally, through public lectures which were well visited, I was also able to communicate findings to tour guides who occasionally come to scientific talks to learn more about the current state of science in the archipelago to communicate these to visitors.

5. Are there any plans to continue this work?

Yes, there are, and I am excited about them! This Rufford conservation grant has been instrumental in my professional development has allowed me to return to the Galapagos Islands and reiterate my lifelong interest and commitment to protecting giant tortoises and Galapagos ecosystems. To this date, I continue actively contributing to research and conservation of Galapagos giant tortoises on a variety of topics. These range from creating maps for various reports, up to translation of scientific results into Spanish, helping write research permits and publications, and popular articles (in Spanish and English).

I plan to return to the Galapagos in 2023 thanks to additional external funding and re-run the nesting algorithm. In addition, staff at the University of Southern Illinois will continue this work as they are increasingly interested in the evolutionary ecology of migration of female tortoises and how this may impact their nest site choice. This is

critical as global change may rapidly alter migration of tortoises while invasive species pose an acute threat for survival of tortoise nests and baby tortoises. I look forward to returning to the Galapagos for the first time since 2019 and contribute to giant tortoise conservation and hopefully find more fresh nests and protect these.

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

As indicated in this report, I have already shared the results of this work extensively through writing popular articles, book chapters, academic publications, giving public and scientific talks. A more complete breakdown of these activities is below. In addition, I plan to continue these activities and will make sure to highlight the Rufford Foundation logo at the end of these talks.

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

Looking ahead I cannot help but to look back. This is because when this project started, I just was embarking on my own PhD journey, which is now in its 5th year. Fast forward from 2018, I have been working in the Galapagos and with giant tortoises for over a decade! A global pandemic has passed, and I had unexpected health complications occur which have changed several aspects of my life.

On the research/conservation angle, the most important next steps are to continue ensuring nesting site protection of Galapagos giant tortoises as well as educational campaign of local youth. I am a bit sceptical of the added benefit of the initially proposed drone aiding the discoverability of nesting sites, as our improvised 'drone less' workflow worked out quite well and is thus much more accessible and replicable in other areas of the world. I believe that keeping invasive species controlled and in low numbers in Santa Cruz, particularly feral pigs, goats, and fire ants is critical for the survival of critically endangered giant tortoises. For this continued close dialogue with the Galapagos national park is critical. On a conservation front, the nesting algorithm can continuously be refined, and I propose to perform another field campaign in 2023 thanks to external funding obtained. I further plan to continue my involvement and closer cooperation with the Southern University of Illinois, in order to ensure that the research and evidence supported by this grant can be used for further scientists (besides my ongoing close collaboration with the local Charles Darwin Foundation and Galapagos National Park).

On a larger scope, this project has allowed my professional development of research in the Galapagos and situate myself as one of the leading early career scientists performing research and conservation in the Galapagos. Thus, I will continue to thrive towards working with local communities in the archipelago and support local youth in their educational and professional development on the longer term. For example, I have provided mentorship to a local former student of the Thoams de Berlanga High School.

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?

I used the Rufford Foundation logo for a large number of public speaking events in Ecuador, Germany, United Kingdom, and the United States. I explicitly acknowledged support from the Rufford foundations during these talks. Examples (in Chronological order) include:

August 2019 Scientific Talk, Charles Darwin Foundation, Santa Cruz, Galapagos, Ecuador Invited speaker: Opportunities and challenges of studying biodiversity patterns in the age of big data.

October 2018 Scientific Talk, Keynote speaker, Royal Geographic Society London, London, United Kingdom. Invited Speaker: Using emergent technologies for conservation science in the Galapagos.

October 2018 Scientific Talk, Keynote speaker, British Chelonian Group, Chester, United Kingdom. Keynote speaker: Using emergent technologies for conservation science in the Galapagos.

July 2018 Scientific Talk, Charles Darwin Foundation, Santa Cruz, Galapagos, Ecuador
Invited speaker: Opportunities and future technologies to investigate movement ecology in Galapagos and in the world.

June 2018 "Meet a scientist" – project of student participation, Tomas de Berlanga High school, Santa Cruz, Galapagos Ecuador
Invited speaker on new technologies for conservation and research in the Galapagos.

May 2018 Opening Symposium of the Max Planck-Yale Center for Biodiversity, Animal Movement and Global Change, New Haven, USA
Invited speaker: Biologging of Galapagos tortoises.

February 2018 International Society of Tropical Foresters, New Haven, USA
Flash talk on: Giant tortoises as gardeners of the Galapagos Islands

In terms of publications, the following articles acknowledged funding from the Rufford foundation.

Blake S., Tapia P.I., Safi K., Ellis-Soto D. – "Diet, Behaviour and Activity patterns". (2020). Galapagos Giant Tortoises Academic Press 207-239.

Ellis-Soto D, Ferraro K, Rizzuto M, Briggs E, Monk J, Schmitz OJ. A methodological roadmap to quantify animal-vectorized subsidies (2021) Journal of Animal Ecology. Best early career review paper of 2021. doi.org/10.1111/1365-2656.13538.

Sommeille, M & Ellis-Soto D. Linking animal migration and ecosystem processes: data-driven simulation of seed dispersal by migratory herbivores (2022) Ecology and Evolution <https://doi.org/10.1002/ece3.9383>

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

Dr. Stephen Blake is the coordinator of the GTMEP and has performed research on Galapagos tortoises for over a decade. His knowledge on these animals, local stakeholders, outreach organizations and NGOs in the island will allow this project to maximize its influence well beyond a purely scientific scope. Dr. Blake co-supervised both my B.Sc. and my M.Sc. thesis. During this project Dr. Blake provided important logistical support and was critical when writing parts of this project into a book chapter for giant tortoise ecology.

Dr. Kamran Safi is a world leading expert in analysing biotelemetry data and was my main M.Sc. thesis supervisor. In 2016, while living in Galapagos, he created the algorithm that can identify potential nesting sites. His support on further refining the proposed framework will be essential. Furthermore, he will provide expertise in bioinformatics and fieldwork. Dr. Safi was critical for developing this algorithm and was very helpful in 2018-2020 when discussing how to implement and run the nesting algorithm R code both when I was in the Galapagos and when I was performing analysis remotely.

Dr. Jorge Carrion is the science director of the GNP, and critical to effective collaboration between this project and the park service. Dr. Carrion will ensure that the project meets the needs of the GNP, is smoothly integrated within the park workplans ensuring the sustainability of the project impact. Dr. Carrion became the director of the Galapagos national park in 2019 and was very interested in findings of nesting zones of Galapagos giant tortoises.

Dr. Sebastian Cruz is a native resident of Santa Cruz Island and a movement ecologist. His relationships with local stakeholders and the Galapagos community as a whole also will be beneficial for maximizing the project impact. He will assist with fieldwork, flying the drone and analysing the data once he has been trained on running the algorithm and identify nesting sites.

Dr Cruz is a field assistant of the GTMEP and his support with monitoring and performing fieldwork will be essential for this project. Being a local and a father of two; he will further support communicating science to the local youth participating in this project. Dr. Cruz was instrumental when performing drone flights to look at nesting sites of Galapagos giant tortoises.

Freddy Cabrera is a lifelong resident of the Galapagos and the leading field biologist of the giant tortoise ecology movement programme. Freddy has extensive experience working with giant tortoises in the Galapagos and working with the local community, park rangers and managers. Freddy has extensive knowledge and experience tracking tortoises and finding tortoise nests. Freddy has been an integral part of this project and has well established relationships with local high schools, ecology clubs and NGOs working on outreach in the Galapagos.

Anna Guezou is a local resident of the Galapagos and has been performing both research and scientific communication and outreach for several decades in the

archipelago. Funded by Galapagos Conservation Trust, she is instrumental in communicating scientific findings and promoting scientific education and conservation at local high schools and with educational non-profits involving both local and international students.

10. Any other comments?

This project has been pivotal for my continuous involvement in the Galapagos during my PhD dissertation at Yale University. It has allowed me to participate in numerous discussions around the future of giant tortoise conservation and establish and continue relationship building with the local Galapagos community, the national park and the scientific and conservation bodies operating in the archipelago. It has cemented to what, to date, is over a decade of living, conserving, and exploring the Galapagos Islands. I hope to play a small role in giant tortoise conservation until the last of my breadths. Thank you for believing in this project. Sincerely, Diego.