A Galapagos giant tortoise hatchling takes its first tentative steps © Sam Rowley

AN INTERIM REPORT TO THE BRITISH CHELONIA GROUP

Conserving the Galapagos giant tortoise: First steps towards lifetime tracks

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Conserving the Galapagos giant tortoise: First steps towards lifetime tracks

An Interim Report by the Galapagos Conservation Trust & the Giant Tortoise Movement Ecology Programme (GTMEP) prepared for the British Chelonia Group

Reporting Period: March 2015 – October 2015

Project Dates: March 2015 – March 2016

Project Lead: Dr Stephen Blake (GTMEP)

Project Partners: Galapagos Conservation Trust, Max Planck Institute of Ornithology, Charles Darwin Foundation, Galapagos National Park, Ecology Project International, Zoological Society of London, British Chelonia Group

Introduction

This interim report describes activities undertaken and preliminary results obtained during the first year of funding for the "First steps toward lifetime tracks" project of the Galapagos Tortoise Movement Ecology Programme (GTMEP). As an interim report, this is not an exhaustive summary of all activities but an overview of achievements and tangible outputs to provide an assessment of progress to date.

The GTMEP has been active for six years. We started as a small and simple research programme with the goal of answering a single fundamental question: "Do Galapagos tortoises on Santa Cruz island undergo seasonal long distance migrations?". Upon answering this question (Blake *et al*. 2013), and proposing a mechanism for the migration based on tortoises maximising intake of high quality forage, we expanded the study to examine tortoise movement ecology across several islands, species and morphotypes to determine how environment, physiology and life history interact to determine movement strategies. As part of this larger study, we:

1. Deployed GPS tags onto tortoises on Isabela island (Alcedo volcano), Espanola island, and increased our sample size of adults, sub-adults and juveniles on Santa Cruz island.
2. Developed our research on the ecological role of tortoises in seed dispersal and vegetation dynamics (Heleno *et al*. 2011, Sadeghayobi *et al*. 2011, Blake *et al*. 2012).
3. Began a study on nesting behaviour, hatchling survival and movements on Santa Cruz island upon which most of the current report is based.
4. Initiated an outreach and education programme to translate and disseminate our research results to local people, decision makers in Galapagos and an international audience.

A major gap in our knowledge for giant tortoise conservation is around the life history stages from egg to juvenile where mortality rates are highest and a serious population bottleneck exists. These stages are often called "the lost years" because few data exist on growth, mortality rate and causes of death of infants and juveniles for many species of wild tortoises and turtles including the Galapagos giant tortoise. Although they are not thought to move over large distances, giant tortoise hatchlings are small and often concealed for several years in dense undergrowth or within the cracks of old lava flows. This makes monitoring large numbers of hatchlings over time very difficult. Preliminary data collected by the GTMEP indicate that mortality rates of eggs can exceed 50% due to predation by non-native feral pigs and fire ants. With increased understanding of these vulnerable life stages, conservation management strategies

can be put in place to reduce the impact of factors causing high mortality. This project aims to address this issue by providing the first quantitative data around key parameters of Galapagos giant tortoise reproduction and hatchling survival.

Objectives for the "First steps towards lifetime tracks"

The **research objective** is to build a robust research programme to answer the following questions:

1. What are the patterns of seasonal abundance and behaviour of adult female Galapagos tortoises at known nest aggregation sites and do nesting females display strong site fidelity?
2. Do environmental conditions influence the timing of nesting?
3. How does the timing of nesting, incubation temperature, egg size, clutch size, hatching success, hatchling survival, hatchling growth rates and movement patterns vary by nest aggregation site and environmental conditions?

Galapagos giant tortoise eggs and hatchlings are vulnerable to the impacts of invasive species such as feral pigs and fire ants © GTMEP

Our **conservation objective** is to increase the survival of eggs and hatchlings on Santa Cruz by developing a closer collaboration with the Galapagos National Park to harmonise data collection and analysis of monitoring data collected by park rangers that will highlight the immediate need to improve nest protection and inform adaptive management. Attempts are made to protect large numbers of nests from predation by pigs, however protection methods are rarely successful at saving nests from predation and better systems need to be put in place. Robust documentation of the high failure rate of protection methods is a first step toward generating the will to develop more efficient alternatives.

Field Assistant Fredy Villamar measures a hatchling – if this tortoise makes it to adulthood, it could live for up to 150 years! © GTMEP

The **outreach objective** is to build on the previous work of the GTMEP to inspire conservation ethics and scientific enquiry among young people both in Galapagos and internationally. We propose to (a) directly engage 150 local Galapagos high school students into our research programme through a long standing collaboration with the Ecology Programme International (EPI), (b) hold a workshop for educators from the Galapagos National Park and teachers from the local community on Galapagos toward the integration of our research into their curricula , (c) develop similar tools with GCT's "Discovering Galapagos" initiative and the education department of ZSL London Zoo for visitors to the zoo and international users though internet applications, (d) finish a 30 minute film with the National Geographic Channel on the GTMEP that will use tortoise borne video via the Crittercam system.

Activities initiated and achievements during this reporting period as summarised overleaf.

1. Research Activity Update

Tortoise Reproduction: *Nest characteristics by nesting zone*

Since the start of this project, a total of 29 tortoise nests were closely monitored along varying elevations of Santa Cruz island; nine in the lower nesting zone, and ten in each of the middle and upper nesting zones (Figure 1). Each nest was carefully opened when freshly constructed, and eggs were counted, measured and marked before being returned into the nest in the exact order in which they were removed. A total of 294 eggs were weighed and measured. Temperature logging "i-buttons" were placed in 24 of these nests, in some cases at the top and bottom of the egg clutch and on other occasions in the middle of the clutch. For some nests, additional i-buttons were placed in holes dug into the soil at the same depth as controls. The i-buttons were programmed to record temperature every four hours.

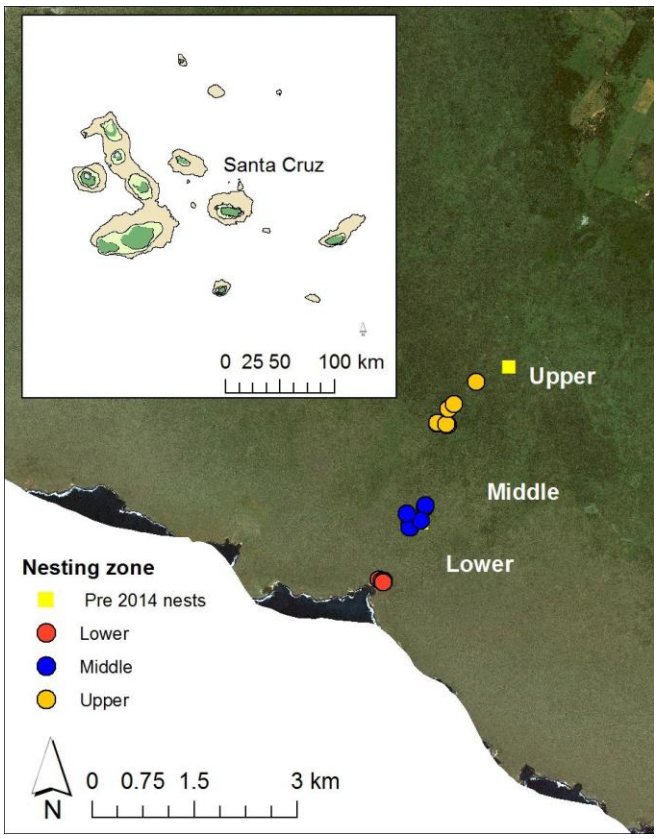


Figure 1. Nests monitored during this reporting period

Nests were checked regularly over the following months and more intensively when hatching and eruption of the nest was expected. It is the policy of the Galapagos National Park Service to open known nests when park wardens expect hatching to be completed and assist hatchlings to excavate the nest. This means that we do not know the exact date of either hatching or when eruption would have taken place naturally, and therefore we cannot provide accurate estimates of incubation time.

On opening the nests, we recorded how many eggs had hatched successfully, and how many were rotten. We counted live hatchlings in each nest before weighing and measuring them. A sample of individuals were fitted with very high frequency (VHF) radio-telemetry tags. An effort was made to sample from numerous nests from each nesting zone, however the actual sample was based heavily on the availability of hatchlings. Nevertheless, we obtained a reasonable spread of nests across sites.

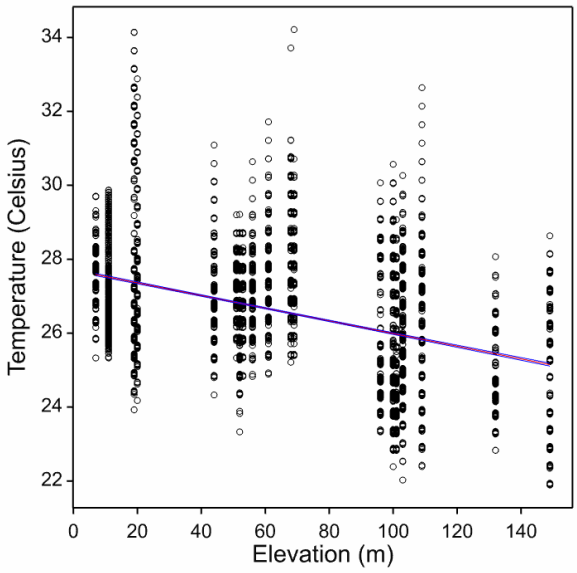


Figure 2. Nest temperature decreases significantly with elevation (all data pooled for illustrative purposes)

First results have suggested that there is no significant difference in the number of eggs per clutch at different nest elevations but weight was significantly higher in the mid zone. The kinds of analyses we will complete using the ibutton temperature data are illustrated in Figure 2 – this shows the decrease in mean nest temperature measured from the centre of nests, revealing a mean temperature difference of 2 degrees (Celcius) over just a 140m elevation range

(10-149m). Given the critical role of incubation temperature on sex and survival, such differences may play a strong role in tortoise population dynamics. Figure 3 reveals the dramatic change in temperature in both nest and surrounding soil through the incubation period, which ranged from 23.4 -27.5 degrees (Celcius) inside the nest. Secondly the graph shows that the temperature within nests is generally significantly cooler than in the surrounding soil though in the last month before the nest was opened, the temperature inside the nest was higher than the surrounding soil.

Cooler temperatures may be due to the effect of the hard crust that the mother tortoise constructs over the nest from a mixture of soil and urine. We will have a full analysis of all the nest monitoring data prepared for the final project report.

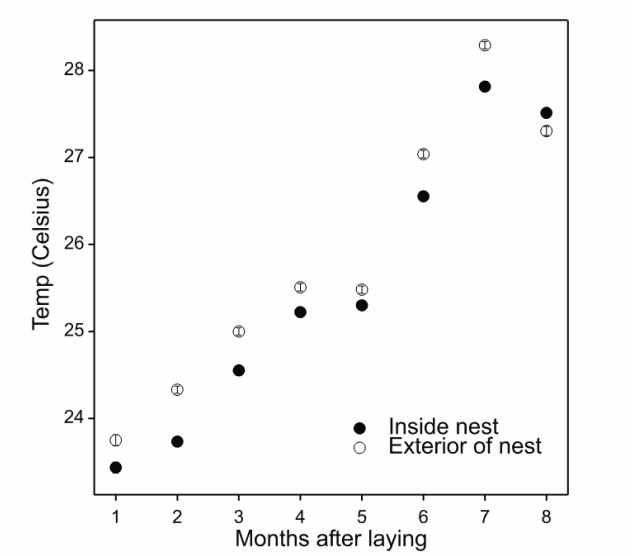


Figure 3. In the middle nesting zone, temperatures inside nests were lower compared to outside the nest at the same soil depth. Temperature increases significantly with time since laying.

Survivorship of eggs appears to decrease markedly with increasing elevation (Table 1). In the lower nesting zone, ca. 71% of eggs hatch successfully, compared to just 40% in the upper nesting zone. It is hard to identify the causes of this difference, however waterlogging during the rainy season and cooler incubation temperatures are probably involved. It is possible that this effect is aggravated during El Niño seasons due to the increased rainfall – this is a concern for 2016.

Nesting Zone	No. Nests	No. Eggs	Successful incubations	% failed incubations
Lower	4	30	30	28.6
Middle	7	45	45	33.8
Upper	10	42	42	60.4

Table 1. Survivorship of eggs by nesting zone for the 2014 – 2015 cohort (based on incomplete data).

Hatchling success, growth, and movements

We attempted to tag two individuals from five nests within each of the three nesting zones. The small sample size is due to current funding constraints, and the logistical difficulties of radio-tracking in remote areas of Galapagos. Radio transmitters are attached to the shell using superglue and are <5% of hatchling body weight. For each tortoise fitted with a tag, we know the nest location, incubation temperature and clutch characteristics. The location, length, width, and weight of each infant tortoise are recorded bi-weekly thereafter.

A Galapagos giant tortoise hatchling is weighed and fitted with a VHF transmitter © GTMEP

We have found considerable differences in survivorship, growth and home range size with elevation. Growth varies seasonally with a peak from February to March during and after the rainy season in the lower and middle zones. Overall, growth is markedly slow in the upper nesting zone compared to the lower and middle zones (Figure 4).

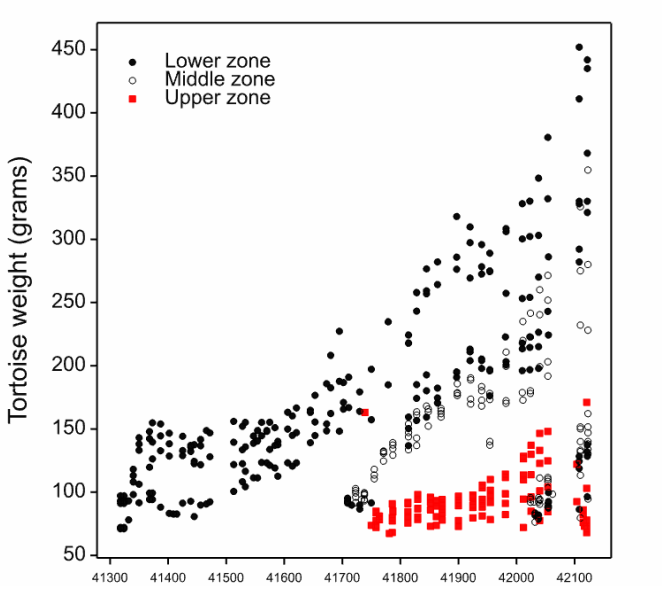


Figure 4. Weight of tortoises over time by nesting zone reveals that tortoises from the lower and middle nesting zones increase rapidly in weight compared to those from the upper zone.

The reasons for these differences between clutch characteristics and the success of hatching and nesting are unclear at present. Our impression, largely supported by the data, is that the middle nesting zone appears to be most favourable for tortoise reproduction. Lower egg and hatchling survival, coupled with slower growth of hatchlings indicate poor overall reproductive success for females that choose to nest in the upper nesting zone. If this proves to be true – why would a female chose this zone? This then becomes a centrally important question for the movement ecology strategies of giant tortoises and for future research.

Tortoise movement ecology

During the reporting period to date we continue to monitor the movements of over 60 juvenile, sub-adult and adult tortoises from four species on three different islands: Santa Cruz, Espanola and Isabela (Alcedo volcano). These data (for which collection began in 2009) have provided the key dataset for most of our scientific papers either submitted or published so far this year (see next section). Our telemetry project will continue throughout 2015 with more publications due for 2016.

Papers published and submitted

1. The Dominance of Introduced Plant Species in the Diets of Migratory Galapagos Tortoises Increases with Elevation on a Human-Occupied Island. Biotropica. 47: 246-258
This paper received considerable press internationally and nationally in Ecuador and the Galapagos Islands. Notably it was featured on the National Geographic News, Reuters World Press, and the Discovery Channel News, as well as being selected as Editor's Choice by the journal Biotropica.

2. Walking with giants: Allom.0etric and temporal scaling of movement characteristics in Galapagos tortoises
Submitted to the Journal of Animal Ecology.

3. A Bioenergetics Model Explains Size-Biased Partial Migration in Giant Galapagos Tortoises
Submitted to Ecology Letters (Ranked second in ecology journals).

4. Flexible characterisation of animal movement behaviour using net squared displacement in a mixture distribution framework
Submitted to the Journal of Movement Ecology.

2. Conservation Activity Update

So far during this reporting period we have not made solid progress toward our goal of harmonising data collection on nest characteristics between the Galapagos National Park Service and our project to improve both nest protection and to better understand the dynamics of nesting. The Park puts a significant amount of effort into monitoring and protecting nests on Santa Cruz, yet the data are seldom available for analysis. As we enter the nesting season of 2015, we will be holding talks with the Park wardens responsible for nest monitoring in an attempt to agree on a standardised data collection and storage protocol.

In a different domain, we are currently working with both the Galapagos National Park Service and the Charles Darwin Foundation on zonal planning for the Galapagos National Park. Our tortoise movement data represents the biggest database of georeferenced animal distribution for Galapagos, Ecuador, and one of the largest available anywhere around the world. We will be developing resource election models, utilisation distribution models describing critical habitats for tortoises and modelling likely migration corridors on Santa Cruz that could play an important role in maintaining connectivity between the highlands and lowlands. Although it is unclear what the outcome of these debates may be, we intend to remain part of the stakeholder forum to ensure that essential considerations for giant tortoise ecology are voiced.

Finally, we have been asked by the Galapagos National Park Service to assist in the development of tortoise-farmer relationships in the highlands of Santa Cruz. As Galapagos farmers come under more pressure from government to improve the productivity of their lands, there is a strong danger that more intensive farming practices will reduce the habitat available for tortoises during their critical upland migratory phase. Currently tortoises enjoy relatively open farm lands dominated by cattle production. Few farmers have fencing or sensitive crops within the tortoise range. However this is set to change in coming years. Loss of habitat at either end of the migration or blockages to migratory corridors can be catastrophic to migratory species, and we suspect tortoises would be no exception. In December of 2015, we will be meeting with the Galapagos National Park Service and the Ministry of Agriculture representatives to discuss applied research to help better understand the potential problems and seek solutions.

3. Outreach Activity Update

Since the beginning of 2015, we have built significantly on the outreach work carried out in recent years. Notable preliminary activities and outcomes include the following:

1. Completion of the GTMEP programme web site in Spanish.

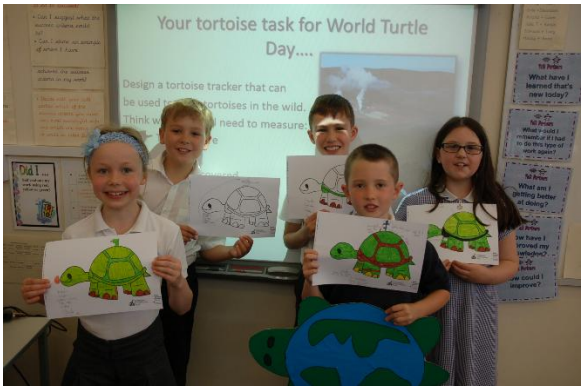
2. The compilation of Spanish versions of recent reports provided to decision makers in the Galapagos National Park Service.

3. Provision of support to the Mola Mola Ecology Club. The Mola Mola Club is a group of young conservation and ecology enthusiasts based on Santa Cruz. We have developed various activities within the club to teach awareness and understanding of tortoise movement ecology and its implications for conservation. Some 20 students were involved in a multi-week activity entitled

"Mapping your Community" in which they mapped the distribution of their activities, favourite and outstanding places, and other areas of interest. The principles of space use and movement between important areas of each student's habitat were related to how tortoises and other animals move within their environment. These exercises are to be adapted for the Discovering Galapagos educational programme that is linked to both the UK and Ecuadorian curricula.

4. We coordinated and implemented a workshop on Experiential Learning Techniques for teachers across Galapagos. The objective was to work with teachers who are tasked with the management of school science clubs mandated from the Ministry of Education to introduce them to informal and formal experiential learning techniques based on the scientific outputs of the GTMEP. The workshop was over three days and involved 11 teachers from three islands. Other delegates included environmental educators from Ecology Project International (EPI), Houston Zoo, Jen Jones from GCT and three PhD students from the UK studying elements of evolution education. An evaluation revealed that teachers found the workshop valuable and rewarding, and strongly felt that the materials covered would help them to develop and implement effective science club activities in their schools. We will be following the progress of the clubs throughout the coming year.

The Mola Mola club prepare to talk to the public about the project and Galapagos teachers learn what it takes to be a tortoise tracker during the 2015 teacher workshop in partnership with EPI © GCT



GTMEP is a great example of how collaboration in international outreach can increase impact. Students in the UK were excited that children all around the world were getting involved with World Turtle Day! © GCT

5. We hosted an open day in the Galapagos National Park to celebrate World Turtle Day on 23 May 2015. Students from the Mola Mola Club constructed a 3D model of the Galapagos Islands and used it to describe and explain the fundamentals of tortoise movement ecology on Galapagos. Posters illustrated the plight of tortoises and turtles around the world, and the important role Galapagos can play as ambassadors for tortoise conservation. The event was open to the public and was well attended by Santa Cruz residents, mostly families, who despite a heavy thunderstorm came to participate in the event.

6. Continuing our partnership with ZSL London Zoo, we produced an educational leaflet for World Turtle Day and conducted several UK school visits. In addition to the activity undertaken in Galapagos, there were also events held in the USA – a truly international outreach collaboration using an iconic species to raise awareness of large scale conservation issues.

Conclusion

We have made satisfactory progress so far during this reporting period, delivering on most of our objectives. The science side of the project is proceeding well, and the education component is collaborating well with local institutions and ensuring widespread dissemination of results of our programme to young people on Galapagos and internationally. For the end of 2015 and early 2016, the key focus will be to harmonise data collection on nests and incubation success with the Galapagos National Park Service to significantly increase sample sizes of nest survival, and the impact of predation and protection.

We are extremely grateful for the ongoing support of the British Chelonia Group and look forward to updating you on our progress for this grant period with a full report in March 2016.

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