Researching the lost years

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Introduction

Losing a Galapagos giant tortoise may sound like an impossibility; after all, they are the largest living species of tortoise in the world and can weigh up to 300 kilograms, but these enormous reptiles begin life as hatchlings a mere six centimetres in length. When you visualise one such hatchling surrounded by the landscape of the Galapagos Islands, a rugged terrain strewn with lava stones and boulders that were spat forth from deep within Galapagos' volcanic hotspot centuries ago, it becomes easier to understand how they can become lost from sight.

Due to this cryptic early life, very little is known about the first few years of a giant tortoise's existence, hence why they are generally referred to as the 'lost years'. However, these lost years are not exclusive to Galapagos' famous residents. In fact, the infancy of many chelonian species is shrouded in mystery because they are often too small to be tracked effectively. Hatchling mortality can also be very high meaning that huge numbers of hatchlings would need to be tracked for a reliable study. As a result, a fundamental part of chelonian life history has gone undocumented for a long time but, in the age of technology, some answers are beginning to emerge.

Turtle trackers

Historically, it was assumed that neonate (newly hatched) sea turtles were 'passive drifters', spending their lost years at the mercy of oceanic currents (Carr 1987; Collard & Ogren 1990), but recent research has disproved this theory.

In 2014, Mansfield *et al.* published an article presenting their findings from the first ever successful satellite tracking study of neonate sea turtles. Having fitted small solar-powered satellite transmitters onto 17 juvenile loggerhead turtles (*Caretta caretta*) collected from nests along the south-east coast of Florida, the team released them into the Gulf Stream and subsequently tracked their movements for the next 1-7 months. Their findings suggested that the tagged individuals were initially transported by the current, but after several months they 'ejected' from the Gulf Stream into areas which offered more favourable conditions for growth and development (Mansfield *et al.* 2014).

Following on from this success, Putman and Mansfield (2015) attached a further 44 satellite transmitters onto yearling turtles in the Gulf of Mexico (20x Kemp's ridley turtles (*Lepidochelys kempii*) and 24x green turtles (*Chelonia mydas*)). Alongside each turtle that they tagged, they released two floating buoys, each with its own satellite transmitter, to directly test the 'passive drifter' hypothesis. Their findings, published in a report in *Current Biology* in April 2015, provide concrete evidence that juvenile turtles are in fact very active swimmers; the turtles' tracks quickly diverging from those of the buoys (Putman & Mansfield 2015).

Unfortunately, the same tags are not suitable to track juvenile Galapagos giant tortoises. Turtle hatchlings cover distances of hundreds of kilometres, so the type of tag required to track them can afford to have a large spatial resolution, meaning that they are only accurate to within several kilometres. Tortoise hatchlings on the other hand cover distances of several hundred metres, so tracking them requires a much smaller spatial resolution and there is not yet a satellite tag small enough to attach to a hatchling which can achieve this. However, a dedicated team of scientists are now undertaking ambitious research in an effort to uncover the lost years of giant tortoises.

Galapagos giant tortoises and Congolese forest elephants

In 2009, Dr Stephen Blake started the Galapagos Tortoise Movement Ecology Programme (GTMEP) with seed funding from the Max Planck Institute for Ornithology and in collaboration with the Galapagos National Park (GNP) and the Charles Darwin Foundation (CDF). The initial aim of the GTMEP was to investigate a claim made by Galapagos islanders to Charles Darwin during his visit to the Archipelago in 1835.

Whilst on San Cristobal, Darwin had observed that giant tortoise trails could be several kilometres long and often went up and down the slopes of the volcano. When he asked the locals about this, they told him that it was because giant tortoises migrated over large distances. This was a statement that he was never able to confirm and one which remained a mystery for the next 175 years, although evidence from the GNP and CDF had suggested large-scale shifts in tortoise distribution on the inhabited island of Santa Cruz. Realising the potential significance of this claim to both the science of movement ecology and giant tortoise conservation, Dr Blake and his team attached satellite tags onto ten tortoises on the island of Santa Cruz to establish whether or not tortoises did indeed migrate.

Prior to his work in Galapagos, Dr Blake spent more than 15 years in the Congo River Basin studying the ecology of African forest elephants (*Loxodonta cyclotis*). Whilst forest elephants and giant tortoises are distant in terms of their geography and evolutionary history, many parallels exist between their ecological roles. Most obviously, both species are large terrestrial herbivores that eat a wide range of vegetation, but it is the result of their herbivory where the strongest similarity can be drawn.

Giant tortoises and forest elephants are both opportunistic frugivores, meaning that they will gorge themselves on fruit when it is available. Whilst the flesh of a fruit is digested, the seeds within it generally remain intact and, after a time, they are 'deposited' in a fresh pile of nutritious dung. Given that it can take a long time for the seeds to work their way through the digestive tract (up to a month in giant tortoises), the seeds are likely to be deposited far away from the parent plant. This seed dispersal plays a pivotal role in vegetation dynamics and, in the case of forest elephants at least, can help maintain biodiversity (Blake *et al.* 2009). Research by Dr Blake has shown that giant tortoises distribute seeds from at least 34 native species of plant (Blake *et al.* 2012) and that a single pile of giant tortoise dung can contain up to 6,000 seeds. African forest elephants are known to disperse seeds from at least 96 plant species (Blake *et al.* 2009) and are thought to be one of the most effective and important seed dispersers in the tropics (Campos-Arceiz & Blake 2011). This makes both forest elephants and giant tortoises 'keystone' species and marks their conservation as critical to the ecosystems they inhabit.

Movement ecology

It may seem obvious, but to successfully conserve a species it is important to know where individuals of the species spend their time, and that means studying their movements. After a year of data had been collected from the ten tags on Santa Cruz, Dr Blake and his team from the GTMEP analysed the movements of the tagged tortoises. Their tracks showed a clear migration up and down the slopes of the volcano. They found that during the cool, dry season (June to December) the tortoises spent their time in the highlands, but when the season changed and it became hot and rainy the tortoises migrated back down the volcano to the lowlands. Interestingly, they found that this migration was not driven by the changing temperature (as you may expect for an ectotherm) but coincided with changes in the vegetation. Furthermore, only adult tortoises were observed migrating, with juveniles and sub-adults remaining in the lowlands year round.

During the dry season, the lowlands of Galapagos' islands become relatively barren and feeding opportunities for tortoises become scarce. At the same time of year, the highlands continue to be relatively humid and the vegetation remains lush and green. It is this more dependable forage that attracts tortoises to migrate up to ten kilometres up the slope of the volcano; a big feat for a slow-moving giant. However, when the rainy season kicks in, the lowland vegetation that has been dormant during the dry months begins to flourish once again. This rapid bloom in new nutrient-rich plant growth is what draws the tortoises back down to the lowlands, completing their migration cycle.

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Galapagos giant tortoises mate throughout the year, but activity peaks between February and June which coincides with the rainy season. As the dry season begins, male tortoises return to the highlands, while females remain behind to lay eggs. Some of the females migrate all the way down to the coast to lay their eggs; however, others have been observed nesting at altitudes of up to 1,000 metres on some islands. Following nesting, some females will then move into the highlands, whilst others will remain in the lowlands year round. What factors affect where a female tortoise nests and whether or not she then stays in the lowlands or migrates to the highlands remain a mystery. How nesting site affects the survival of eggs and hatchlings is another unknown. It is these questions which the GTMEP is now trying to answer.

In 2013, Dr Blake and his team began a pilot project to test research methods for determining nest characteristics, egg hatching success and offspring survival across an elevation gradient of 150 metres on Santa Cruz. Data collected from nests in three distinct altitudinal zones revealed several significant differences in nest characteristics. Firstly, nest temperature differed by an average of 3.8°C between the hotter lower site and the cooler upper site. Given that tortoises, like many reptiles, have temperature-dependent sex determination, this temperature gradient is likely to significantly affect the sex of hatchlings. The data also showed that whilst clutch size was comparable across sites, the weight of eggs laid in the middle nesting zone was significantly heavier than at the other two sites. A trend in hatching success could also be seen from the data, with success decreasing as elevation increased, although a larger sample size is required to confirm this.

In addition to collecting nest and hatching characteristics, the team also collected the first ever movement data for wild hatchling giant tortoises. When hatchlings began to emerge from nests in the three different elevation zones, the heaviest individuals were selected for tagging, simply because these individuals could cope with carrying the transmitters (although ideally hatchlings of all sizes would be tagged to ensure an unbiased sample). Having affixed miniature radio transmitters weighing just 6 grams onto the hatchlings' shells (Fig.1), they were released and allowed to go their separate ways. Following this, members of the GTMEP team returned to the nesting sites every 1-2 weeks, armed with a VHF receiver which they used to track down the hatchlings before recording their positions. For the first several months of tracking, hatchlings were observed moving steadily further away from their nesting sites. However, after this initial dispersal the team found that the majority of hatchlings then seemed to stay within a relatively small 'home patch' of several tens of square metres. The reason for this abrupt stop has yet to be determined, but the GTMEP team will continue to monitor

Fig. 1. The tortoise nicknamed 'Moz' with a VHF transmitter affixed to its shell. Photo © S.Blake.

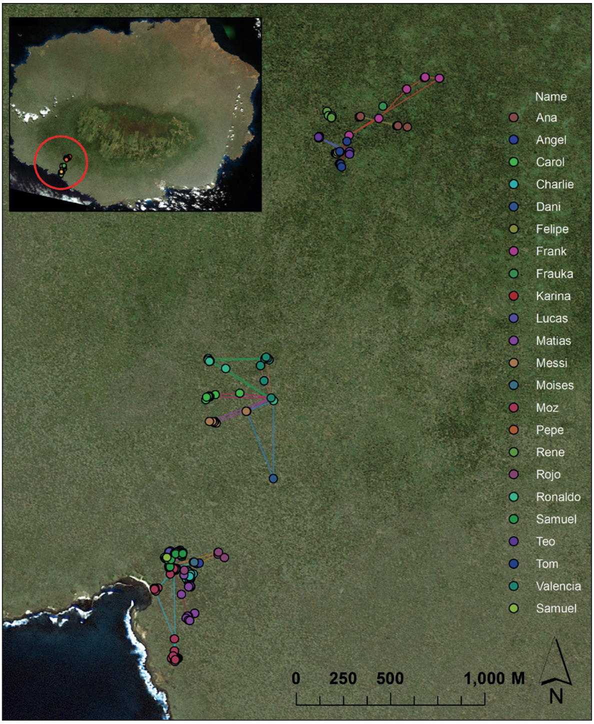

Fig. 2. Tracks from 23 VHF tagged giant tortoise hatchlings.

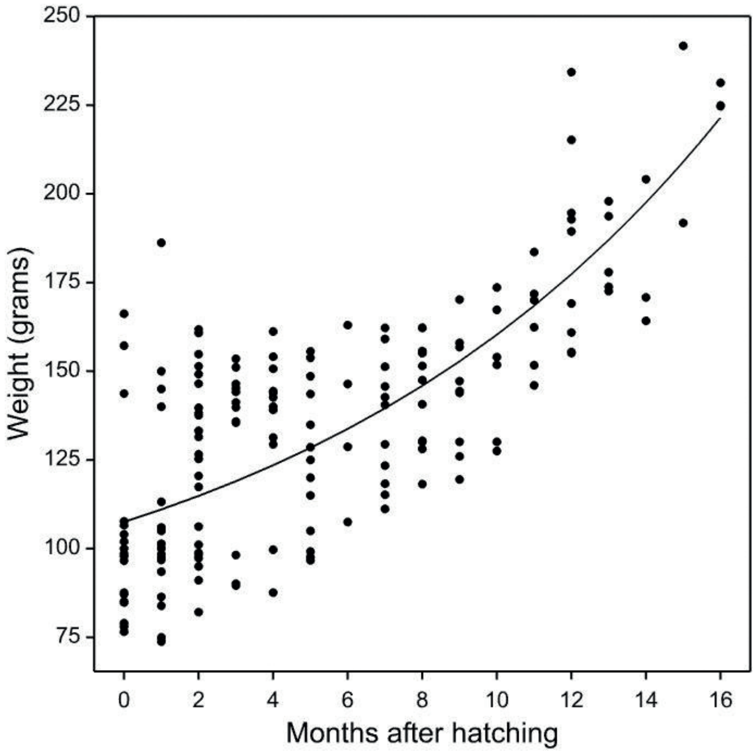

Fig. 3. Weight increase in Galapagos giant tortoises after hatching.

these hatchlings to see how long they remain resident. Tracks from 23 tagged individuals can be seen in Figure 2.

As well as tracking the movements of hatchlings, the GTMEP team also measured changes in the size and weight of individuals in order to establish growth rates. It was found that after relatively slow growth in the first months of life the hatchlings grew rapidly during the heavy wet season and had almost doubled in weight after the first year (Fig. 3).

After the success of the pilot study and having refined the methodology necessary to research such small tortoises, the team are expanding the project. Now in their second year, the plan is to monitor 40 nests across the three nesting sites and to tag an additional ten hatchlings from each nesting zone in order to learn more about their dispersal and movements.

Threats to hatchlings

The early years of life are often when animals are at their most vulnerable. Many species of chelonia experience high mortality rates during this stage of life, primarily due to predation, which is why clutch sizes tend to be large. In Galapagos, giant tortoises have been relatively predator-free for the vast majority of their several-million year stay on the islands, the only real threat being from Galapagos hawks (*Buteo galapagoensis*). Unfortunately, those threats have significantly increased since the islands were discovered by humans nearly 500 years ago.

Historically, tortoises were exploited by whalers and pirates, who found that giant tortoises made the perfect 'living larder' for long journeys as they could be stored upside-down in ships' holds and survive without food or water for more than a year. Whilst direct exploitation has fortunately now ceased, the indirect threats brought about by humans remain a conservation challenge.

Introduced species are the single largest threat to island ecosystems. They are also the primary cause of death among hatchling giant tortoises in Galapagos. Feral pigs, dogs, cats and rats are all extremely effective predators which will locate and feed upon tortoise eggs as well as hatchlings. Fire ants can also devastate entire nests as they swarm over hatchlings that are emerging for the very first time. A host of organisations are working to control and eradicate invasive species in Galapagos but while the threats persist effective conservation management strategies are required in order to protect the native wildlife.

Research application and outreach

The research being undertaken by the GTMEP is essential for the long-term conservation of giant tortoises. Understanding how, when, where and why young tortoises live and die will help to inform the Galapagos National Park authorities about how to provide sufficient protection to tortoises at this critical life stage. Identifying the factors that affect the survival of hatchlings will help to predict future population trends, and successfully conserving them will ensure that there is a next generation of adult tortoises in the making.

In addition to conducting the scientific study, Dr Blake and his team have been developing a number of tortoise outreach and education activities. Working in collaboration with Ecology Project International, they have been taking high school-aged Galapagos students on field workshops to inspire them to pursue careers in science and conservation. They have also been developing teaching materials for school-supported science clubs with the Ecuadorian Ministry of Education as part of a government-led initiative to increase extra-curricular learning. In the UK, they have provided material for the Galapagos Conservation Trust's education programme, Discovering

Galapagos. One of the outputs from this has been the development of a tortoise-themed education pack for use by school groups visiting ZSL London Zoo.

Whilst many questions remain about the reproduction, migration and infancy of Galapagos giant tortoises, Dr Blake and the GTMEP team are making significant inroads into our understanding of these fundamental life-history characteristics. If their research and their success continue it may not be long before the 'lost years' becomes a misnomer, as what once was lost may well have been found.

Acknowledgements

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References

Blake, S., Deem, S.L., Mossimbo, E., Maisels, F. & Walsh, P. (2009). Forest elephants: tree planters of the Congo. *Biotropica* 41(4): 459-468.

Blake, S., Wikelski, M., Cabrera, F., Guezou, A., Silva, M., Sadeghayobi, E., Yackulic, C.B. & Jaramillo, P. (2012). Seed dispersal by Galapagos tortoises. *J. Biogeogr.* 39(11): 1961-1972.

Campos-Arceiz, A. & Blake, S. (2011). Megagardeners of the forest – the role of elephants in seed dispersal. *Acta Oecologica* 37: 542-553.

Carr, A. (1987). New perspectives on the pelagic stage of sea turtle development. *Conservation biology* 1(2): 103-121.

Collard, S.B. & Ogren, L.H. (1990). Dispersal scenarios for pelagic post-hatchling sea turtles. *Bulletin of Marine Science* 47(1): 233-243.

Mansfield, K.L., Wyneken, J., Porter, W.P. & Luo, J. (2014). First satellite track of neonate sea turtles redefine the 'lost years' oceanic niche. *Proc. R. Soc. B* 281: 20133039. http://dx.doi.org/10.1098/rspb.2013.3039

Putman, N.F. & Mansfield, K.L. (2015). Direct Evidence of Swimming Demonstrates Active Dispersal in the Sea Turtle "Lost Years". *Current Biology* 25: 1-7. http://dx.doi.org/10.1016/j.cub.2015.03.014