Comparing the rate of growth of Asian water monitor lizards (*Veranus salvator*) in forest and agricultural habitats, within the Lower Kinabatangan Wildlife Sanctuary and surrounding areas.

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Word Count:

## Placement reflection

During my year at the Danau Girang Field Center I was immersed in a completely different culture and environment. My placement brought me to the front line of conservation efforts, as I was able to get involved with a variety of projects, which focused primarily on understanding the impacts of habitat fragmentation.

After spending a couple of weeks at DGFC I was drawn in by the Monitor lizard (Biawak) project, which is lead by Sergio Guerrero Sanchez. Having already run for three years I was lucky enough to join for the fourth and final year of trapping. Together we discussed the idea of studying the rate of growth of the monitor lizards and got started right away. Under his supervision he taught me how to safely handle and sample the monitor lizards. Field work extended into lab work as blood samples had to be processed for future analysis. The project required careful planning, leadership and confidence to run smoothly and safely, I feel over the year I absorbed these attributes myself. During my time at DGFC I wasn't focusing purely on the monitor lizard project, a number of projects at DGFC required the help of placement students and volunteers. I was able to assist with the sampling of Civets, Pythons, Crocodiles, Slow Loris and Tarsiers. A lot of these animals were tagged with VHF/UHF/GPS radio collars in order to study the spatial ecology of these species. It was the responsibility to the PTY students to track and download the data from these collars in order to help establish home ranges for the tagged individuals.

The centre receives visitors from many different cultures and backgrounds, it was my responsibility to teach and promote the importance of the work being carried out at the centre. I also escorted our visitors into the forest to carry out primate surveys, night walks and canopy climbing. With visitors also came the opportunity to present our personal projects, throughout the year I was able to gain more confidence in public speaking. PTY students were also responsible for writing and editing the monthly newsletter "jungle times" improving my written communication.

Overall my year working at DGFC has taught me more than I could have imagined it would, its taught me that I can live in a harsh and isolated environment, it has improved my communication both scientifically and socially and finally it has highlighted to me the importance of conservation efforts.


## Abstract

The biodiversity found in Sabah, Borneo is under extreme threat from habitat fragmentation; this is due the exponential increase in deforestation for palm oil plantations. Although the consequences of habitat fragmentation are severe for the overall biodiversity of Borneo, palm oil plantations have opened up a new niche and opportunity for more generalist species, such as the Asian water monitor lizard (*Varanus salvator*). Growth rate can be used to represent the fitness of an individual or population. It highlights how energy can be used to increase in size, yet maintain vital physiological processes, in order to amplify competitive ability. Using the *V. salvator* as an indicator species, the aim of this is project is to use their rate of growth to study the viability of both forest and agricultural habitats (Oil palm plantations), and to understand the affect fragmentation has on the species. Growth rate was measured using the change in snout to vent length (SVL) divided by the time between captures in a capture–mark–recapture study, in both secondary forest and oil palm plantations, between 2013 and 2017. *V. salvator* caught in oil palm plantations have a significantly faster rate of growth than *V.salvator* caught in secondary forest. It is expected that oil palm plantations give rise to pest species that provide an abundant food source for the Asian water monitor lizard, however further research into their movements and food availability is required to fully understand what drives their high rate of growth.


## Introduction

Habitat fragmentation is currently the biggest threat to biodiversity in Borneo, it is estimated that between 1973 and 2010 the state of Sabah has lost 39.5% of its forest area to make way for industrial timber and oil palm plantations (Gaveau et al. 2014). The leading producers in the palm oil industry are Malaysia and Indonesia comprising of 80% of worldwide production, but together these nations are also home to greater than 80% of south east Asia’s remaining primary forest (Koh and Wilcove 2007). The biodiversity within agricultural land is significantly lower than primary forest as well as disturbed secondary forest. A study carried out by Fitzherbert et al. (2008) showed that less than half as many vertebrate species are found within oil palm plantations when compared to primary forest. Also of species across all taxa found in primary forest, only 15% of them were also found in oil palm plantations.

To fully understand the effects of fragmentation, it is important to focus on indicator species (IS). “Indicator species can be used as a tool to assess the short-term impacts of environmental changes and the potentially damaging consequences of long-term ecological shifts” (Siddig et al. 2016). To do this a number of different species dynamics can be examined, including abundance, reproductive success and growth rate. Looking at growth rate shows us how successful an individual/population is, as it reflects the allocation of energy among physiological processes, essential to survival. This includes growth, storage, maintenance and reproduction (Laver et al. 2012). A high growth rate demonstrates that an individual/population is able to support these functions and retain enough energy to continue to grow, maximizing body size and in turn providing individuals with a competitive edge when it comes to competition and survival (Cabrera-Guzmán et al. 2013).

The Asian water monitor lizard (*Varanus salvator*) is an ideal indicator species as it can be found in both forest and agricultural habitats, enabling us to accurately compare the short-term impacts of environmental change (Siddig et al. 2012). *V. salvator* is the second largest lizard species in the world behind the Komodo dragon (*Varanus komodoensis*) yet the water monitor is regarded as the most widespread Varanid species (Koch et al 2007). Water monitors are generalist feeders, their diet consisting of a wide range of vertebrates, crustaceans and carrion (Shine and Harlow 1998). The conversion of forest into oil palm plantation affects the Asian water monitor lizard as it creates a fragmented landscape, which may impact the movements and distribution of the species. This in turn may result in a narrowing genetic diversity (Dixo et al. 2009), which could lead to a high vulnerability to pathogens (Pearman and Garner 2005). The species could also be exposed to an increased level of ultraviolet light and environmental pollution (Mijanur and Iliazovic 2016).

The dramatic increase of oil palm plantations is not only detrimental in itself; it elicits an increase in human settlement, leading to an increase in human trophic subsidies and human-animal conflict (Campbell-Smith et al. 2012). Human trophic subsidies can have both positive and negative effects on animals that consume them. The maintenance of a productive oil palm plantation often depends on herbicides and pesticides. The chemicals used in pesticides and insecticides are often lipid soluble, if consumed they can become incorporated into the fatty tissues of animals. As a consequence of this, chemicals will bio-accumulate as they are trophically transmitted, which means that the highest concentration of chemicals will be seen in predators (Tan and Mustafa 2004). A modified diet may alter phenotypic traits that could improve fitness and positively influence population growth rates by improving their reproductive success and survival. However a modified diet could just as easily have the opposite effect and prove damaging to the health of the population (Jessop et al. 2012).

The body condition of an individual can be used as an indicator of its fitness (Warner et al. 2016), as body condition is an estimation of the fat stores in an individual. A more successful individual will have a higher body condition as it will have more food stored in the form of fat bodies (Case and Schwaner 1992). However in habitats exposed to human trophic subsidies, body condition may not represent the health of individuals or populations as a whole. We can look at the difference in body condition between recaptures to understand whether individuals in agricultural habitats are gaining weight relative to their body size and compare this with the change in body condition of lizards in the forest habitat, ultimately to compare the fitness of both populations.

The aim of this study is to use the rate of growth of monitor lizards found in forest and monitor lizards found in agricultural habitat as an indicator as to how viable each habitat is and the affect fragmentation has on the species. The main hypotheses of this project are:

- There will be a significant difference between the average rate of growth of *V. salvator* found primarily in forest habitats and *V. salvator* found in agricultural habitats (oil palm plantations).
- The average rate of growth of *V. salvator* found in agricultural habitats will be higher than the rate of growth of *V. salvator* found in forest habitats.
- Smaller lizards will have a faster growth rate than larger lizards

## Materials and Methods

### Study Site

The study was undertaken at various sites in the Lower Kinabatangan Wildlife Sanctuary (LKWS). The LWKS is located in Eastern Sabah (5◦10′–5◦50′N; 117◦40′–118◦30′E) (Ancrenaz et al. 2004). The sanctuary's terrain is made up of a variety of habitat types including: seasonally flooded forest, riparian forest, dry dipterocarp forest, mangrove and swamp forest (Estes et al. 2012).
The protected forest is bordered by multiple oil palm plantations creating a fragmented habitat for a vast majority of species in the LKWS. Transect sites were selected based on interior and edge habitats of both oil palm plantations and forests of the LWKS (see Figure 1).

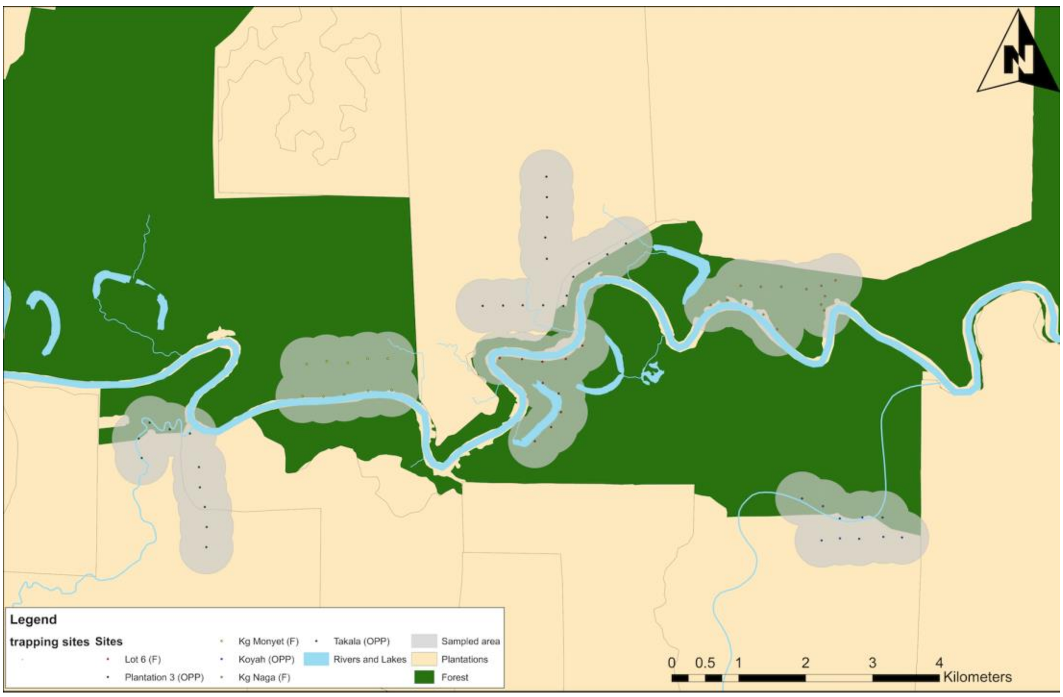


**Figure 1 shows the positions of each transect within our sampling area. There are three sites in oil palm plantation (cream) and three in secondary forest (green), each with an interior and edge transect.**

**Lizard Trapping**

In order to study rate of growth of water monitor lizards, the capture, mark, recapture method was used (Laver et al. 2012). Box traps, baited with chicken guts, were placed at 400 m intervals along 1.6 km long transects, totalling five traps per transect, with two transects at each trap site, an interior and edge transect. An equal number of trap sites were placed in forest and plantation habitats. Each transect was visited three times over a four-year period as part of the monitor lizard project conducted by PhD student, Sergio Guerrero Sanchez.

**Sampling**

Lizards were removed from the traps using a noose pole, which restrains the movement of the individual; this allows safe control of the head and hind legs of the animal. When the lizard is removed from the trap, its legs were tied, mouth secured with a cable tie and a cloth placed over its eyes to calm it and reduce stress, as it does with crocodilian (West et al. 2014). Body mass (kg), snout to vent length (SVL), total body length, head length and tail length was measured for each individual. They are marked using a sub-dermal microchip in the right hind leg for identification if recaptured.

**Rate of growth**

Growth rate of individuals was calculated using data collected in previous years by Sergio Guerrero-Sanchez, and an additional six months of data collected in 2017. This will provide a total of four years of captures and recaptures data. Measurements for rate of growth will only be taken if recapture time interval is greater than six months in order to minimise error. SVL was the primary morphological subject of our study as it is widely regarded as the most accurate measurement when analysing growth (Forsman 1993, Laver et al. 2012). Other morphological elements will also be analysed, including total length, tail length and body weight.

The change in SVL will be calculated by subtracting the SVL at the date of recapture from the SVL at the date of original capture. The rate of growth will be calculated by dividing the change in SVL by the time (months) between each capture. If multiple recaptures occur we will take the SVL at the most recent capture event. Negative growth rates will be included as individuals can loose weight in response to limited resources or senescence (Wikelski and Thom 2000 cited in Laver et al. 2012).

**Analyses**

All statistical analyses were done on statistical software R Studio Version 1.0.143. We looked at the average rate of growth (RoG) of monitor lizards in forest habitat and compared it with the individuals found in oil palm plantations. We split the lizards into group based on their size at first capture, as we were unable to estimate the age of the lizards. Body condition was calculated using the residuals of regression between the $\log_{10}$-transformed body mass and $\log_{10}$-transformed SVL (Smyth *et al*., 2014). As with rate of growth, the change in body condition was calculated by subtracting the body condition at most recent recapture from the body condition at the original capture.

## Results

### Scope of Data

Over 400 individual monitor lizards were caught between 2013 and 2017, 756 recaptures allowed us to record growth rates from 80 individuals. Of these 80 individuals 72.5% were recaptured more than once during the sampling period. A total of 46 growth rates were recorded from individuals caught in secondary forest compared to 34 in the oil palm plantations. Recapture intervals used for analysis spanned from six months to three and a half years, recapture intervals less than six months were excluded.

### Rate of Growth

The data was assessed for normality and was transformed using log(x+1) in statistical software R, however the data after transformation could not be normalised. Therefore, the non-parametric Kruskal-Wallis test was used to compare the growth rate of the SVL of *V. salvator* in both forest and agricultural habitats.

There was a significant difference between the average rates of growth of *V. salvator* found in oil palm plantations and secondary forest (Kruskal-Wallis chi-squared = 4.4718, df = 1, p-value = 0.03446), confirming that habitat selection can affect the success of individuals and populations. There was a significant difference between the average SVL of lizards, at first capture, found in forest and agricultural habitats whereby lizards caught in oil palm plantations have a significantly larger average SVL than lizards caught in secondary forest (Kruskal-Wallis chi-squared = 1045597, df = 2, p-value $<2.2e^{-16}$). Lizards caught in the oil palm plantations also have a faster average rate of growth. Confirming the hypothesis that the average rate of growth of *V. salvator* found in agricultural habitats is higher than in secondary forest (Figure 2).

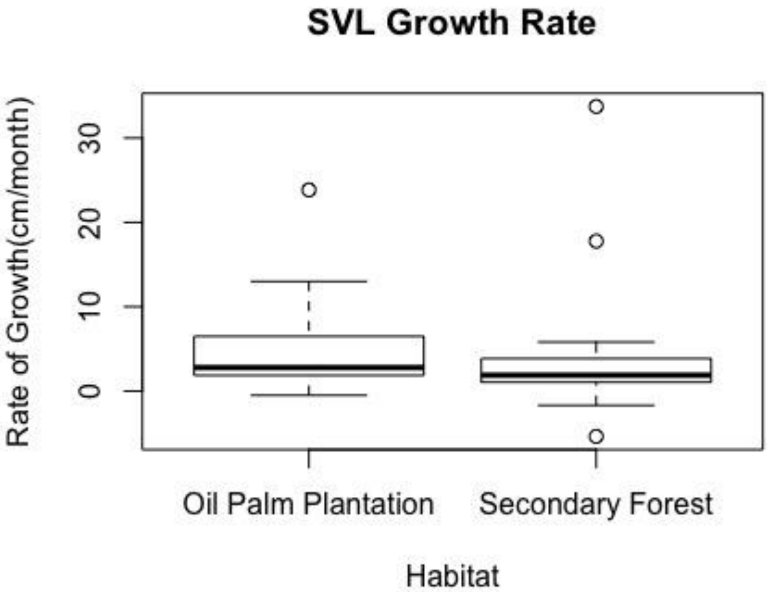


**Figure 2 features a boxplot to describe the difference in SVL growth rates between *V. salvator* found in oil palm plantations and secondary forest.**

The growth rate of body weight was significantly higher in individuals found in oil palm plantations compared with those found in secondary forest (Kruskal-Wallis chi-squared = 10.0865, df = 1, p-value = 0.0015). However there was no significant difference when comparing the growth rates of the tail and the total length in both habitats (p>0.05)(Table 1).

**Table 1 shows the average growth rates of monitor lizards in both forest and agricultural habitats, measured in cm/month with the exception of body weight, which is measured in kg/month.**

| Morphological Element | Average Rate of Growth | | Kruskal-Wallis chi squared test | | |
|---|---|---|---|---|---|
| | Oil palm plantation | Secondary Forest | K | df | p-value |
| **SVL** | 4.46 | 3.02 | 4.4718 | 1 | 0.0345 |
| **Body Weight** | 0.14 | 0.05 | 10.0865 | 1 | 0.0015 |
| **Total Length** | 0.57 | 0.24 | 3.4712 | 1 | 0.0625 |
| **Tail Length** | 0.13 | 0.22 | 0.6078 | 1 | 0.4356 |

To test the hypothesis that smaller lizards will have a higher rate of growth than larger lizards, individuals were split into 11 groups based on their size at first capture at intervals of equal size from 40cm to 95cm. Group 4 was the largest with 22.5% of all the individuals used for assessment fitting into the 55-60cm category, whereas groups 1,9 and 11 only had two individuals. The Kruskal-Wallis test was used to compare the average rate of growth from each size group.

There was no significant difference between the groups (K = 5.7517, df = 10, p-value =0.8357) allowing us to accept the null hypothesis that smaller *V. salvator* do not have a faster rate of growth than larger *V. salvator* (see Figure3). There was also no significant difference between the groups when we compared the habitats separately, (K = 5.4319, df = 10, p-value =0.8605) in the secondary forest and (K = 9.4532, df = 9, p-value = 0.3965) in the oil palm plantations.

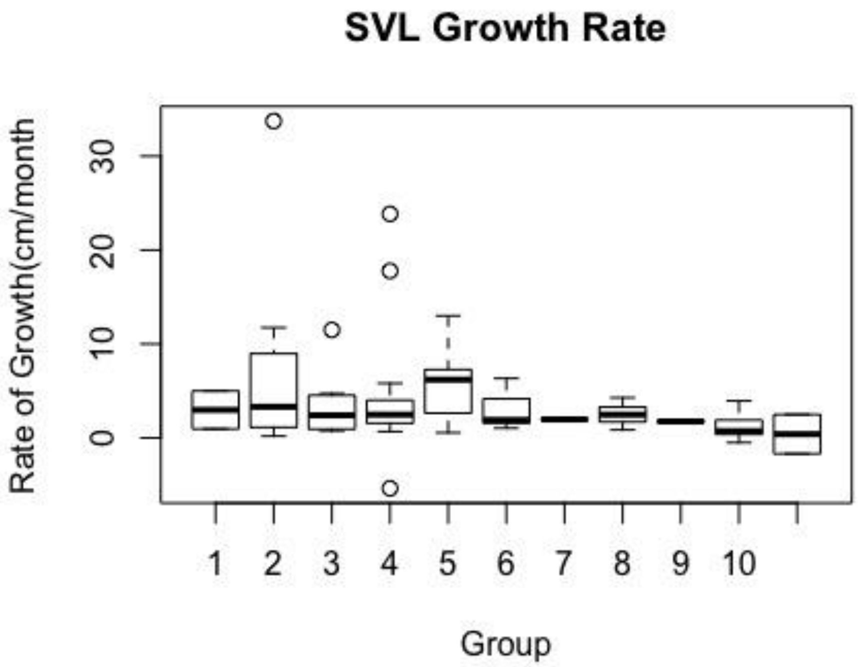


**Figure 3 visualises the growth rates of each size group, there is little variation in the medians of each group.**

**Body Condition**

To help us understand whether the rapid increase in body weight is having a negative effect on the fitness of lizards found in oil palm plantations we compared the change in body condition between recaptures of lizards from both habitats. This proved not to be statistically significant ($p>0.05$), however the change in body condition cannot solely be the indicator for the fitness of the populations.

## Discussion

Studying somatic growth rate allowed us to gauge the success of a population as it can have important fitness consequences, be heritable, and evolve (Caley and Schwarzkopf 2004). Here we used rate of growth to indicate the success *V. salvator* have in both secondary forest and oil palm plantations, and have discovered that there is a significant difference between the growth rates in each habitat. Not only are oil palm plantations able to support the Asian water monitor lizards, they are able to provide enough resources for the individuals to grow significantly faster than in secondary forest.

When the rainforest is cleared for oil palm plantations there is a major shift in resource consumption. For specialist species this is less favourable as habitat fragmentation will limit the resources available to them, this in turn opens up a niche for the generalist species, with less competition for resources and the ability to utilise and adapt to new resources they are able to thrive (Martinson and Fagan 2014). Because of this oil palm plantations often give rise to pest species such as rats, which are known to reach densities of 600 individuals per hectare (Wood and Fee 2003), providing an abundant food source for predator species. This could explain why the average growth rate of *V. salvator* is faster in oil palm plantations than in forest habitats.

Ectothermic species rely on the external temperature for development and growth. Zilber et al. (1991) recorded a significant increase in growth of captive Nile crocodiles, *Crocodilus niloticus* when subject to higher temperatures and direct sunlight. That environment is reflected in oil palm plantations as compared with secondary forest, oil palm plantations have very little canopy cover. This means that *V. salvator* living in oil palm plantations are more exposed to direct sunlight and higher temperatures than the individuals living in the forest (Davis and Sutton 1998), this could be another factor driving the high growth rate of lizards in oil palm plantations.

The body weight and SVL of monitor lizards in the plantations grew significantly faster than lizards in the forest. Yet there was no significant difference in the change in body condition of monitor lizards in both habitats. Body condition is directly affected by both body weight and SVL; therefore as both are increasing at a similar rate, the body condition will remain constant. Although body condition helps us to understand the fitness of individuals and populations as a whole, it cannot be the sole method of analysing the health of an individual/population.

There are a number of factors that we are unable to account for and the majority of them stem from our inability to sex each individual. Externally Asian water monitor lizards do no display sexual dimorphism, so it is impossible to determine the sex of lizard non-invasively. The difference in rate of growth of male and female monitor lizards is due to the difference in energy allocation between the sexes. Female growth is driven by fecundity, so reproduction is prioritised over somatic growth whereas males are driven by sexual selection, this means that energy is focused on somatic growth in order to improve their ability to compete for females (Laver et al. 2012). By assessing the rate of growth without any indication of sex, it is likely that the average rate of growth is not truly representative for each habitat.

The individual lizards were put into groups based on their size at first capture, this was to test the assumption that younger lizards will have a faster growth rate, however without the sex of the lizard there was no way to estimate the stage of its life cycle. This could explain why there was no

statistical significance between the growth rates of the groups, as the groups could be made of up males, at an early stage of their life cycle, as well as mature females.
With more time we could use molecular analyses to determine the sex of each individual, using PCR primers to amplify sex specific alleles (Laver et al. 2012). With the sex of each individual identified, we can compare the growth rates of males and females separately in each habitat. Also the growth of some individuals reached its asymptote before the final recapture. Leaving an area of doubt when calculating its growth rate, as it meant finding a balance between keeping the methods consistent but gaining a less accurate measure of growth rate. If the study was repeated over a longer period of time we could establish growth curves and an age estimate for each individual in order to get an accurate representation of growth rate and estimation of age. Enabling us to accurately assess the difference in growth rates of individuals at similar stages in their life cycle, in different habitats. Alternatively if we were able to use captive individuals and record their growth from birth it could also be possible to create an average growth curve for both sexes and ascertain the point at which growth rate asymptotes, using this we could estimate where other individuals are in their life cycles.

Each trapping site has an interior transect and an “edge" transect that borders the forest and the plantation. Individuals that were caught when trapping along the plantation edge were categorised into the “Plantation” group, and although the vast majority of plantation lizards were recaptured in the plantations there is no way to ensure that these lizards are not using the forest as well. One of the main focuses of the monitor lizard project was the use of GPS backpacks to monitor the spatial ecology of *V. salvator*. The data collected by Sergio Guerrero Sanchez suggests lizards caught in the plantation interior have the smallest home ranges, which suggests that the oil palm plantation does provide the individuals with the resources they need however further study into their movement patterns and food availability is required to fully understand the factors that drive body size and rate of growth.

## Conclusion

With the global demand for palm oil continuing to increase, more and more forest is going to be destroyed for the production of oil palm plantations. The goal of this project was to use the rate of growth of *V.salvator* as an indicator as to whether oil palm plantations can support this species as its natural habitat is being lost. We have discovered that Asian water monitor lizards are not only able to survive in plantations but thrive, as a generalist species they are perfectly able to adapt to and utilize their new environment.

## Acknowledgements

Firstly I would like to express my gratitude to Dr Benoit Goossens, my placement training year supervisor, for giving me the opportunity to work at DGFC and carry out my own research project. I would like to thank Sergio Guerrero Sanchez, not only for teaching me the skills required to carry out my project but for his guidance and positive outlook on life. I would also like to thank my fellow PTY students, Francis Roy, Jack Devlin and Angus Chaplin-Rogers for making this placement unforgettable. I would like to thank all the students, research assistants and staff at DGFC for welcoming me into their community and teaching me how to survive a year in the jungle. Finally a massive thank you to my parents for supporting me throughout my PTY.

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