Surveying of Armadillo activity in Finca las Piedras

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Abstract

Within the Madre de Dios region, four different species of armadillo are known to range and at least three of these species have been recorded previously within Finca las Piedras. Giant armadillos (*Priodontes maximus*) are one of these species and are currently at risk of extinction according to the IUCN. In this study we surveyed the forested area for armadillo burrows and feeding holes, as well as setting up camera traps at two giant armadillo burrows and one feeding hole. This allowed us a further insight into the behaviour of armadillos and of other species which benefit from the underground structures that giant armadillos create. Positive correlations were found between the width and heights at the entrances to armadillo burrows, feeding holes and giant armadillos feeding holes. Armadillo burrows and feeding holes were mainly found in open areas over termite mounds or beneath trees. Camera traps showed that rodents commonly visited and foraged through soil mounds by new giant armadillo burrows and feeding holes, as did brown agoutis and pacas. Whilst at an old giant armadillo burrow, a south american coati and a brown agouti were recorded entering, yet no rodents were recorded. We presume this is due to the lack of a soil mound at an old burrow in which to forage. Three bird species were also recorded investigating soil mounds at the new burrow and feeding hole, including the blue-crowned motmot. Continued surveying of the property as well as long-term camera traps would allow a more thorough comprehension of the armadillo community at FLP and their importance to other species present.

Introduction

Armadillos are placental mammals in the order Cingulata. Together with sloths (Folivra) and anteaters (Vermilingua) they form the Xenarthra (Superina et al., 2013). They are semi-fossorial, nocturnal animals, that are native to South America (Sawyer et al., 2012). Of the twenty-one extant species of armadillo, four are classified as Vulnerable, four are Near Threatened and four are Data Deficient (Aba & Superina, 2010). In the Madre de Dios region there are possibly four species of armadillo including the giant armadillo (*Priodontes maximus*), nine-banded armadillo (*Dasypus novemcinctus*), greater long-nose armadillo (*Dasypus kappleri*) and southern naked-tailed armadillo (*Cabassous unicinctus*) (Aba & Superina, 2010). Of these *P. maximus* is currently listed as Vulnerable by the IUCN whilst the other species are of 'Least Concern'. However, given the solitary nature of armadillos, data is insufficient to determine their population status. In addition, the rapid degradation to their habitat will continue to affect the stability of their populations in the future. Research suggests that the knowledge about most of the endangered species is scarce and additional studies in some of the South American countries, amongs them Peru, should be made (Superina, 2013). Armadillos play an important role in the ecosystem of the regions they are found in, some even describe them as "ecosystem engineers", as they construct burrows that can present a new habitat for other species as well as positively influencing the soil in many aspects (Sawyer et al., 2012). Using camera traps, previous studies have recorded many different species such as collared peccaries (*Pecari tajacu*), small rodents and other armadillo species using old giant armadillo burrows as secondary burrows (Superina et al., 2017). Some individuals were also seen foraging within soil mounds created from armadillo burrows, whilst others such as the Felidae family were found searching for prey within holes (Superina et al., 2017). More field work is necessary not only to understand the ecological role of armadillos in creating new niches for others within the forest community, but also to help provide more data, which will allow us to create a more accurate estimation of their population status for the purposes of conservation in the future. Therefore, we surveyed the Finca las Piedras (FLP) site for indirect signs of armadillo acitivity during three weeks in August 2018. Surveying consisted of mapping the locations and taking base measurements of burrows and feeding activity as well as setting up camera traps at the entrance of *P. maximus* burrows or feeding holes to ascertain which other species rely upon these structures.

Methods

Data Sampling

Our initial proposal for the project was to survey indirect signs of armadillo activity including their burrows or feeding holes within FLP. FLP is found in the Madre de Dios region of Peru along the newly paved (2008) Interoceanic Highway. The property itself is composed of secondary terra-firme rainforest, cleared spaces and a native food forest currently in development. Surrounding the property, a mixture of secondary terra-firme rainforest, farmed monocultures and cattle ranches can be found. Continual monitoring of the area has included the use of camera traps which have recorded *P. maximus* and *C. unicinctus* to a 100% confidence within the primary rainforest, as well as a recording of either *D. novemcinctus* or *D. kappleri*, either species could potentially be found within the region (Aba & Superina, 2010).

We began our first and second surveys along the main trail where each surveyor focused on one side of the trail in search of activity. Further transects were taken at random points around the property surrounding the main trail as well as encompassing the outer border of the property. A GPS location was taken at each burrow or feeding hole. A tag was similarly placed on a nearby tree to prevent re-sampling.

Initially all burrows or feeding holes which suggested armadillo activity were recorded, however after a few sessions we realised that this was an unattainable goal as the large number of each prevented us from surveying more of the property. It was also hard at times to say without question that a burrow or hole was due to armadillos and not another fossorial species. We consequently altered our project with the purpose of surveying only activity of *P. maximus*. Burrows or feeding holes from *P. maximus* were presumed from the larger dimensions of such holes as stated by Ceresoli & Fernandez-Duque (2012) who described the average dimensions of *P. maximus* burrows.

The following dimensions of burrows and feeding holes were taken: height at the entrance (cm) and width at the entrance (cm) using a tape measure; depth (cm) up to 1 metre using a wire and tape measure in order to navigate turns in burrows; orientation (of burrows only) using a compass; slope of the entrance to the burrow in categories by sight (1 = 0-45°, 2 = 45-75°, 3 = 75-90°). As well as measurements for the different sites we noted characteristics of the microclimates surrounding the burrows and feeding holes. Sites were placed into the following area parameters: fallen trees, standing trees, open areas, termite mounds. When multiple entrances to one burrow were found, only one was measured.

The ages of burrows were then estimated using the following grouping method (Aya-Cuero et al, 2017): New - less than one month old, soil mound created is not compressed, tracks may be found as well as moist faeces, no vegetation present within and no soil erosion within the burrow; recent – soil mound is variously compressed with germinating seedling within the burrow and mound; old – no soil mound present, eroding within the hole or burrow, larger plants growing from within and the tunnel may be filling. Any further features of the burrow and surrounding area were also noted, such as nearby termite mounds, fallen fruits or other anomalies.

Camera traps were set up at the entrances to two *P. maximus* burrows and one feeding hole for roughly two weeks in order to ascertain which other species utilise these burrows and feeding holes. The first of which was set up at a new burrow 06/08/18–14/08/18, found beneath a standing tree off trail. The camera trap gives a view of the entrance to the burrow. The second was set up at an old giant armadillo burrow from 01/08/18-14/08/18, beneath a large tree at the side of a small path. The camera gives a view of the area in front of the burrow as well as a view of the path. The final camera was set up from 31/07/18–13/08/18, the site was a new feeding hole created by a giant armadillo on the weekend of 21/07/18. The camera was set up to give a few of the entrance to the feeding hole & the soil mound created, with a view of the main trail behind.

We created a map using QGIS 2.18, on which our trails and armadillo burrows or feeding holes are shown.

Statistical Analysis

We ran exploratory analysis using correlation tests for continuous data and Kruskal-Wallice tests for categorial data to test for differences in groups such as age and area. For all categories except giant armadillo burrows (i.e. armadillo burrows, armadillo feeding holes and giant armadillo feeding holes), we ran correlation tests with burrow width and height to test whether these two physical parameters vary with each other. We tested assumptions for correlation and performed Spearman correlation tests if assumptions for Pearson correlation were not met. Calculating correlation of width and height of giant armadillo burrows was not possible as only two data points were available. Kruskal-Wallice tests were used as assumptions for ANOVA were not met. Only significant results were included within the results. To further test between which groups the difference exists, we ran Mann-Whitney tests. Data was analysed using R 3.5.0.

Results

Data was categorized. '*P. maximus*' tables contain only data collected from presumed *P. maximus* burrows and feeding holes whilst 'armadillo' tables contain data from all other burrows and feeding holes measured in the first few surveys. We found 23 burrows (armadillo burrows) and 16 feeding holes of smaller armadillos (armadillo feeding holes) as well as 2 burrows and 7 feeding holes of *P. maximus*.

Averages

Average height, width and depth can be found for armadillo burrows, feeding holes, giant armadillo burrows and giant armadillo feeding holes, in Table 1.

A map was also created to show the locations of all burrows and feeding holes measured, alongside transects completed during surveys (Fig.1).

Armadillo Burrows

Armadillo burrow width correlated positively with height at the entrance to the burrow (Spearman correlations=854.36, p=0.001, rho=0.626) (Fig.2). Significant differences were found between the depths of burrows in different areas (Kruskal-Wallis: chi2=13.58, p=0.002). Significant difference was found between open and fallen tree areas (p=0.004); open and standing tree areas(p=0.01); open areas and termite mounds (p=0.004) (Fig.3). From the 24 burrows, 12 were found in open habitat, while we found 6, 4, and 2 in termite mounds, fallen trees and standing trees, respectively. Orientation of the entrances were distributed evenly.

Table 1: Table showing averages and ranges of numerical data from burrows and feeding holes

	Measurement (cm)	Mean	Median	Range
Armadillo Burrows	Height	13.63	13	8-21
	Width	17.37	16.5	10-32
	Depth	86.67	100	44-100
Armadillo Feeding Holes	Height	24.65	25	10-40
	Width	21.94	21	12-32
	Depth	37	38	17-57
Giant Armadillo Burrows	Height	57.5	57.5	37-78
	Width	58	58	48-68
	Depth	100	100	100-100
Giant Armadillo Feeding Holes	Height	43.38	40.5	14-81
	Width	46.5	44.5	28-81
	Depth	76.75	81	45-100

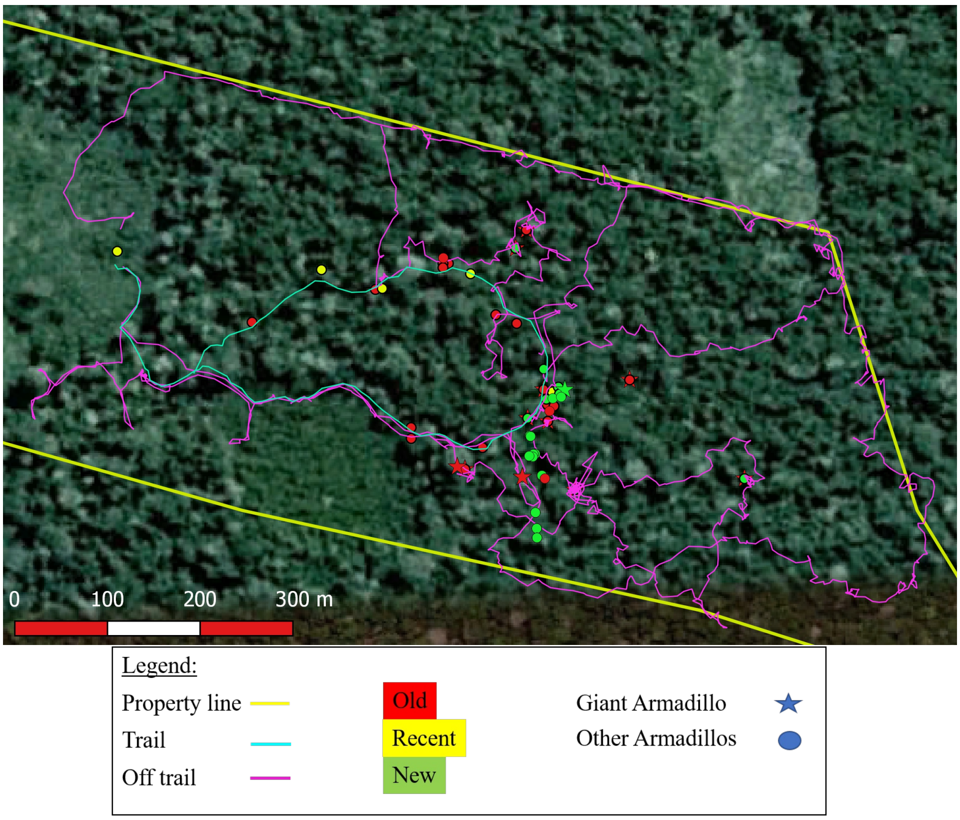

Figure 1: Map of transects, burrows and feeding holes within FLP property

Armadillo Feeding Holes

Pearson correlation showed a positive correlation of armadillo feeding hole width and height (t=3.47, df=15, p-value=0.003) (Fig.4). A significant difference was found between the height at the entrance and age of armadillo feeding holes (Kruskal-Wallis: chi2=9.81, p=0.007). A significant difference was found between recent and new feeding hole depths (p=0.002) (Fig.5). The most common area for armadillo feeding holes was an open area whilst the most common slope was 2.

Giant Armadillo Burrows

Only two *P. maximus* burrows were found. Both burrows were found at the base of a standing tree and a camera trap was placed at the entrance to each.

Giant Armadillo Feeding Holes

Giant armadillo feeding hole width correlated positively with feeding hole height (Pearson correlation: t=3.00, df=6, p-value=0.024) (Fig.6). The most common slope was three for Giant Armadillo feeding holes.

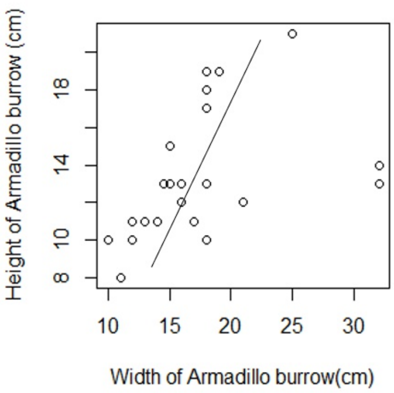

Figure 2: Scatter graph showing height (cm) at entrance to Armadillo burrow against width (cm) at entrance to the burrow

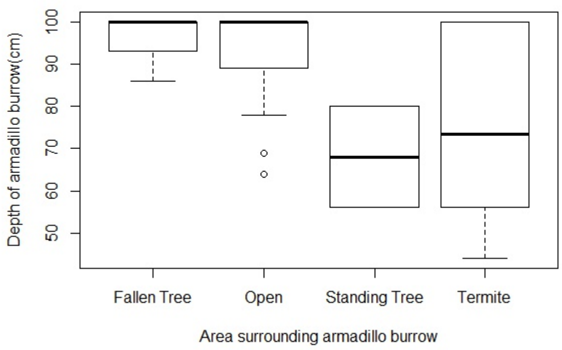

Figure 3: Box plots showing depths (cm) of armadillo burrows in different locations

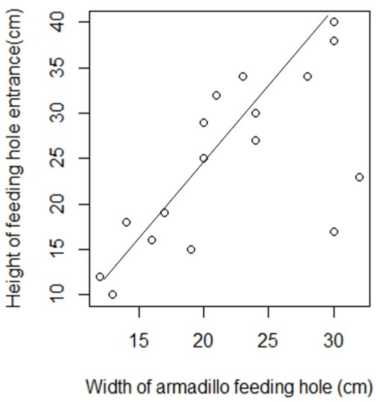

Figure 4: Scatter graph showing height (cm) of entrances to armadillo feeding holes against width (cm) at the entrance

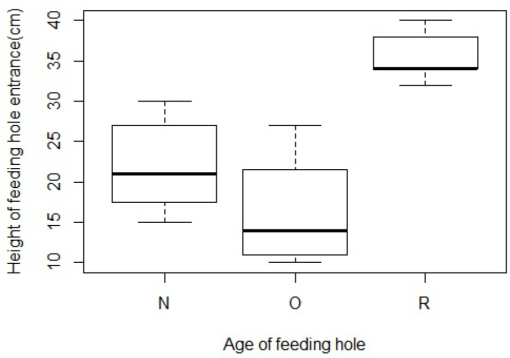

Figure 5: Box plots to show the height (cm) at the entrance of armadillo feeding holes at different ages

Camera Traps

Camera Traps at Giant Armadillo Burrows

One camera at the entrance to a burrow recorded three species of mammals and two species of birds. Two small rodents foraged through the soil mound whilst another walked past the camera. One paca *(Cuniculus paca*) searched the soil mound and overhanging branches. The other two pacas walked past the burrow. One bird (potentially spix's guan (*Penelope jacquacu*)) walked past the burrow whilst a blue-crowned motmot (*Motmotus momota*) investigated the camera (Fig.7).

The second camera trap focusing on an old burrow recorded three species of mammals as well as one species of bird. Brown agoutis were captured in seven videos. One individual was first recorded entering the burrow and then 30 seconds later was caught exiting the burrow. A south-american coati (*Nasua nasua*) (Fig.8) was similarly caught exploring the area around the burrow before entering the burrow itself. One minute later it was recorded exiting the burrow. The other five agoutis simply walked past the burrow, as did a lowland tapir (*Tapirus terrestris*). Three pale-winged trumpeters (*Psophia crepitans*) were also recorded walking past the burrow together.

Camera Traps at Giant Armadillo Feeding Holes

This camera trap recorded three species of mammals and two species of birds. Rats were most common, appearing seven times walking or foraging within the earth mound. Brown agoutis were seen on five occasions, in one video two individuals are seen. Most walked through the earth mound, a few were seen eating whilst one washed (Fig.9). A puma (*Puma concolor*) was also observed using the main trail.

Two birds were also seen visiting the feeding hole. One was observed in two consequent videos foraging through the earth mound, at one point turning over a large block of soil searching for food – looks similar to a Cacique/Oropendola. Another smaller bird was observed flying away from the earth mound.

Discussion

The aim of our project was to survey the FLP property for signs of indirect armadillo activity and to record which species were seen to benefit from armadillo burrows or feeding holes within the terra-firme rainforest. We began surveying the forested area of FLP by recording basic data from armadillo burrows and feeding holes. As the

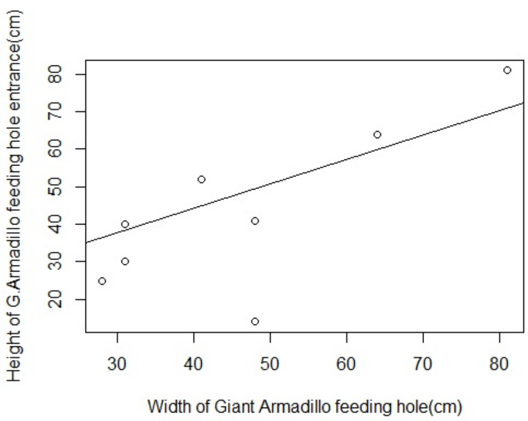

Figure 6: Scatter graph showing height (cm) of entrances against width (cm) at the entrance to the Giant Armadillo feeding holes

Figure 7: Blue-Crowned Motmot at a camera trap positioned at a Giant Armadillo Burrow

Figure 8: South American Coati before entering a Giant Armadillo burrow

Figure 9: Brown Agouti foraging in the soil mound at one of the Giant Armadillo feeding holes

project progressed we narrowed down which sites to measure and focused primarily on identifying burrows and feeding holes of *P. maximus* given previous camera traps in FLP have recorded the species within the area. However, we only found two separate *P. maximus* burrows during our surveys. This was expected given the solitary nature of *P. maximus* and our limited period to survey.

During surveying, a total of 49 sites were measured with only 2 *P. maximus* burrows and 8 *P. maximus* feeding holes. Given this limited data for giant armadillos, conclusions should be drawn cautiously. However, we can compare the dimensions of the two *P. maximus* burrows with averages calculated by Ceresoli & Fernandez-Duque (2012). Ceresoli & Fernandez-Duque's calculated averages were 43(±9) cm width and 36(±7) cm height for the entrance of a *P. maximus* burrow. Whilst burrow entrances we measured had widths of 68cm and 48cm and heights of 78cm and 37cm. The larger width and height measurements were from a burrow we sorted into the 'Old' category. The observed erosion could have led to the larger measurements as the entrance collapsed in on itself. Whilst the other burrow measured was counted as 'New'. The measurements of this burrow were smaller and more similar to the averages calculated by Ceresoli & Fernandez-Duque (2012). Categorizing of burrows and feeding holes into different ages was set prior to measuring and has been previously used by Aya-Cuero et al. (2017). However, during our surveying period, the weather was variable and included days of rain. We can assume that this may have impacted the appearance of the burrow or feeding hole, particularly the soil mound which may have appeared more aged. This could have influenced our interpretation of age. Depths of *P. maximus* burrows also were not calculated given depths of over 100cm which we did not have the capability to measure.

There are fewer studies into *P. maximus* feeding holes, so no prior averages could be used to interpret whether a feeding hole was from *P. maximus* or another armadillo species. However, the age of one of the feeding hole is known to a few days and the size (height: 43.38cm, width 46.5cm, depth 76.75cm) indicates that it was created by *P. maximus*. Similar sized feeding holes were therefore counted as created by giant armadillos. The most common slope angle was of the category 3, meaning it was over 75°. Slopes were estimated into categories by sight. This estimation was made more reliable given two different surveyors however was not an accurate measurement and in the future a clinometer should be used to measure an accurate slope. Besides that, a significant positive correlation was found between the width and height of the entrance to the feeding hole. The correlation is presumably due to the different dimensions of different individuals creating the burrows. It may also be caused by erosion at the same rates on both the sides frim the top of the burrow over time.

Our initial three surveys included measurements of all presumed armadillo burrows and feeding holes. This surveying technique might have been inaccurate as we simply presumed all burrows or feeding holes were from an armadillo species, when in reality other small fossorial mammals such as rodents or anteaters (previously recorded at FLP) could have created these structures.

The average armadillo burrow was of height 13.63cm, width 17.34cm and depth 86.67cm. Burrows with a depth of over 100cm were recorded as 100cm, this could have an impact on results. Many burrows also had multiple entrances and sometimes it was impossible to know if nearby armadillo burrow entrances connected. Armadillo burrows were most commonly found in an open area. The depths of burrows were compared in different areas. Significant difference was seen in the depths of burrows between open areas and all other areas. However, more burrows were measured in open areas so the results are questionable. More data from termite mounds, standing and fallen trees would be required to ensure results are accurate. Analysis of results from armadillo burrows also showed significant positive correlation between width and height at the entrance to armadillo burrows. This correlation presumably occurred as the armadillo individual increased in size, its height and width increased similarly. Dimensions of armadillo burrows were presumed to have been impacted by activity of other species such as rodents which had in some cases created more tunnels from within the armadillo burrow, this complicated which burrow entrances to measure. A similar issue arose within a *P. maximus* feeding hole, in which three separate burrows had been created. Potentially these burrows were created by smaller armadillo species within the feeding hole, which could reduce the physical exertion required to create the burrow given the looser soil, however this could not be proved and we had not previously recorded such activity within the area.

The mean height of armadillo feeding holes was 24.65cm, width 21.94cm and depth 37.00cm. The most common area was open and slope of category 2. Significant difference was found between the depths of recent and new feeding holes. With only five feeding holes of recent age found, despite an obvious difference this could be coincidental. As seen in armadillo burrows and *P. maximus* feeding holes, a significant positive correlation was found between width and height at the entrance of armadillo feeding holes. The dimensions of feeding holes varied greatly, from 10cm to 40cm in height, 12cm to 32cm in width and 17cm to 57cm in depth. These dimensions have a large range and those wishing to carry on surveying FLP for armadillo activity would be wise to create certain boundaries for these measurements for which it is presumed an armadillo created the feeding hole.

Orientation was also noted at armadillo and *P. maximus* burrows given previous studies which found correlations in orientation of armadillo burrows in relation to the climate (Ceresoli & Fernandez-Duque, 2012). We theorized that given the 'friajes' that occur within the region which see cold winds blowing from the South, burrows may be more likely to face North in order to avoid the wind chill. However, we could not draw any conclusions given only two *P. maximus* burrows were found (North West and East respectively) whilst the other armadillo burrows showed a mixture of results. The most common of which being East, South East & West. This suggests that there is no preference for the direction of the burrow entrance. Alongside this, the orientation of six armadillo burrows was not measured given the perpendicular nature of the burrow. Meaning that the burrow had a slope of 90° into the ground but then levelled off further down. However, no previous studies have recorded a perpendicular nature to armadillo burrows, so it should be noted that these may have been created by other semi-fossorial animals. It would also be preferable to have accurate orientation to the degree in order to input data into Rayleigh's test for circular uniformity, future surveys should incorporate this.

Additional observations were also noted during data collection. The area surrounding the burrows or feeding holes was observed for signs of potential food sources. This included some red fruits found at two sites, which could be interesting to see if armadillos feed on these as previous studies have noted the varied diet of *P. maximus* to include figs from *Ficus sp*) (Wallace & Painter, 2013). Termite mounds nearby were similarly noted (if the burrow or feeding hole was not directly into the mound itself), these were found at two different sites. Alongside observations on potential food sources, faeces and tracks were also found alongside the burrow or feeding hole. Other evidence of different animals utilising burrows included the discovery of Brazil nut shells within the burrow, potentially from brown agoutis which are known to feed on Brazil nuts. Alongside evidence of feeding, tracks and faeces were discovered. If possible, it would be useful to be able to identify the species responsible for such evidence at armadillo burrows or feeding holes. This could help to give us a bigger picture of how many faunae within FLP rely upon these underground structures.

Camera traps set up at three separate sites allowed further insight into the use of *P. maximus* burrows and feeding holes alike. Other studies have focused on investigating the use of their burrows such as by Superina et al. (2017), whilst there is less focus on the benefits of feeding holes. Our camera trap at the new feeding hole showed a variety of mammals and birds. Rats, one species of bird and brown agoutis were observed foraging through the soil mound created by the feeding hole. Rats were the most commonly observed animal at the site. A small bird was seen flying away from the soil mound, potentially searching for food, whilst a puma was also seen using the main trail next to the feeding hole. This was the first recording of a puma within the area. Pumas may prey on larger mammals such as *P. maximus*. Meanwhile, the camera trap set up at the new *P. maximus* burrow also saw many rodents such as rats and pacas foraging through the soil mound created. It was not possible to see if any entered the burrow given the angle of the camera. At this camera trap a blue-crowned motmot was recorded on the soil mound observing the camera trap. It was interesting to see this species at the *P. maximus* burrow given a previous study by Superina et al. (2017) also recorded blue-crowned motmots regularly at *P. maximus* burrows.

The final camera trap was set up at an old *P. maximus* burrow on a trail, this camera recorded two species entering the burrow for short spaces of time. One being a south american coati and the other a brown agouti, both entering the burrow for less than a minute. Aside from this pale-winged trumpeters, a lowland tapir and five other brown agouti individuals walked past the burrow. This was the only camera to not record other rodents, which were present on the soil mounds of the new burrow and new feeding hole. From this we can interpret that the dug-up soil mounds created by *P. maximus* are an important resource for these animals whilst foraging for food. Whilst old *P. maximus* burrows could potentially be used for a similar purpose in the search for small invertebrates such as spiders which frequent these structures. Our cameras did not record any animals using the burrows for extended periods of time, however other studies have previously recorded rodents and even other armadillo species using them as secondary burrows (Superina et al., 2012). If camera traps were left up for longer periods of time, we may also have observed the same activity. Surveying of the different animals which rely upon the structures they create is imperative in order to understand their role FLP rainforest ecosystem.

Location of the found burrows and feeding holes shows that armadillos dig several burrows and/or feeding holes next to each other. This conclusion was made on the presumption that the burrows close to each other were made by the same armadillo, based on the same age category and similar dimensions of the burrows and feeding holes. We also found that there were more of them beside the trail than off trail and if off trail, they were on more open areas oppose to dense areas with thick vegetation. However, this may be due to the fact it was easier to spot them on the trails or open areas.

Our methodology in surveying FLP was intended to cover a large span of the forested area, however given the slow pace of measuring each sign of armadillo activity along a transect, we simply chose random transects which therefore had bias. There were also issues in moving through the thick bush layer and consequently our line of vision was impacted in searching for burrows or feeding holes on the ground. In the future surveys would be preferably done in transects to remove bias and previous burrow/feeding holes measured in this study will be recognizable by a labelled tag on a nearby tree. Furthermore, others interested in continuing our project into the future would hopefully find more giant armadillo sites with a more thorough survey of the property, as *P. maximus* has been recorded previously to create a new burrow every one or two nights (Superina et al., 2017). If the study is continued into the future it could also be possible to track for changes in *P. maximus* activity upon changes in the environment, which could become a pressing issue into the future with climate change. More data is necessary to run proper statistics on measurement of Giant Armadillo burrowing and feeding activity.

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