Feeding Ecology of the Blue-Throated Macaw

(*Ara glaucogularis*)

(Photo by Eleanor Collinson)

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Abstract

The aim of this field study was to try and better understand the foraging behaviour and competition surrounding the food resource the Motacu Palm (*Attalea phalerata*). Which both the Blue-Throated Macaw (*Ara glaucogularis)* and the Blue and Yellow Macaw (*Ara ararauna)* species utilises as both a food resource and nesting site. Studies revealed a significant difference in group size for both *Ara glaucogularis* and *Ara ararauna* depending on whether the birds were feeding or not. It was also found that both *Ara glaucogularis* and *Ara ararauna* fed significantly more in intra-species groups than inter-species groups. There was also significantly more inter-specific aggression than intra-specific aggression between the *Ara glaucogularis* and the larger *Ara araraura*. Vegetation studies revealed that different vertebrate species on the reserve consumed significantly different proportions of *Attalea phalerata* nut, with ground foraging mammals consuming the most, followed by *Ara glaucogularis*, then *Ara ararauna*. However, canopy cover was not found to significantly affect the type of species found foraging across the reserve. Black Howler Monkeys (*Alouatta Caraya)* were reported to consume the least. Video footage also confirmed that the two Macaw species utilise the food resource in different ways. *Ara ararauna* was recorded as leaving long scrapings horizontally along the side of the nut, whereas *Ara glaucogularis* would leave either the classical spiral marking as noted by previous studies or a second kind of marking. This was hypothesised to be the precursor to the full spiral marking.

Introduction

Barba Azul.

The Barba Azul nature reserve is situated within the Beni Department or Benis, known locally as the 'Ilanos de moxos'. The Benis are the third largest savannah complex in South America, spanning over 184, 000km, an area twice the size of Portugal (BA website, 2016). This region is largely overlooked by travellers to Bolivia in favour of visiting places such as the salt flats or the Amazon, meaning it does not reap the same benefits from ecotourism that other biodiversity hotspots in Bolivia and South America claim (Zeppel, 2006). The region hosts a wide range of flora and fauna, including many endemic and threatened species such as the Boto River dolphins (*Inia boliviensis*), Marsh Deer (*Blastocerus dichotomus*) and the Blue-Throated Macaw *(Ara glaucogularis)* (Cardoso Da Silva and Bates, 2002). The absence of these species throughout the rest of Amazonia make it a highly valuable ecoregion, in part due to its unique ecosystem goods and services (Larrea-Alcázar et al., 2011).

This ecoregion contains 5 distinctive habitats: savannah, treed savannah (cerrado), forest islands, gallery forests and marsh wetlands. (Armonia,. 2016) The reserve is home to 288 bird species and is the most important stopover in Bolivia for the annual migrations of the buff-breasted sand piper (*Tryngites subruficollis*) (Armonia,. 2016). Recently, the reserve doubled in size. This was due in sum to the combined efforts of Associatión Armonía - who own Barba Azul - and several partner groups to purchase an additional 14,830 acres, increasing the Barba Azul Nature Reserve from 12,350 to 27,180 acres (Boorsma., 2016).

The Barba Azul reserve is heavily ranched by local farmers and large areas of its grassland undergo annual burning to clear the way for cattle (Boorsma., 2016). These fires can quickly spread out of control devastating local wildlife, destroying many foraging and breeding sites and fragmenting habitats (Simard et al., 1985). In the presence of an El Nino event the dry conditions are exacerbated, making life on the savannah particularly perilous for the organisms that dwell there. The year of this research – 2016 – saw 3 such large fires between June and September alone due to the drying effects of El Nino.

Habitat fragmentation is a global risk to species worldwide (Fahrig, 2003). Fragmented landscapes – such as the heavily-ranched areas of the Benis - can lead to an increased risk of inbreeding, which some believe can bring about a reduction in fertility (Hemmings et al., 2012). Many sub-populations on the reserve inhabit these forest islands such as the Black Howler monkey (*Alouatta Caraya)*, the Collared Peccary (*Pecari tajacu)* and the *Ara glaucogularis* and are at risk of this reduced fertility (Olsson and Shine, 1997). Another threat to species on the reserve are the large numbers of escaped, domesticated pigs (*Sus scrofa domesticus)* which are furthering habitat degradation by over foraging of the flora within the forest islands and across the savanna. *Sus scrofa domesticus* are also known to be reservoirs for zoonotic pathogens, which pose a very real health threat to many threatened and endangered species across the reserve (Bevins et al., 2014).

Mammals and birds are key seed dispersers in tropical regions with between 51% and 98% of canopy and sub-canopy trees relying on these species for their seed dispersal (Stoner, K.E. and Henry, M., 2009.) Many tree species rely on vertebrates such as Macaws (*Ara)* and Howler monkeys (*Alouatta*) to ingest their seeds. The process of passing through the digestive tract of these animals removes coatings that would otherwise prevent seed from germinating (Julliot, 1997). *Alouatta*, especially, are known to carry seeds great distances from the parent plant and deposit it in their faeces, which acts a fertiliser for the new plant (Julliot, 1997). Parrots are highly frugivorous and Macaws are known to be key dispersers of seeds throughout many ecosystems (Bravo and Zunino, 2000). The loss of animals that act as dispersers of seeds will have a negative impact on the forests and plant regeneration cycle in the area. The true extent of which we may not see for many years still to come (Muller-Landau, 2007).

The canopy layer of the disrupted Benis landscape is mostly comprised of two types of trees. *Cecropia* trees make up much of the canopy layer. Their abundance is due to their efficient ability to colonise decimated areas, making them a good indicator of the level of disturbance in particular areas (Wardlaw, 1931). Their vast numbers within the reserve serve as a reminder of how volatile these landscapes can be and the adaptability required of the animals that make their home here. *Attalea phalerata* also make up a large percentage of the canopy layer within the forest islands, with large stands being dominated by this species[1]. Their ability to produce fruit year round make them an invaluable food resource for many species (Correa et al., 2012) including the non-migratory *Ara glaucogularis*. Old dead trunks of these trees also serve as a vital nesting sites for *Ara glaucogularis* and *Ara ararauna* (Moraes, M., 2001; Yamashita, C. and de Barros, Y.M., 2013).

Barba Azul is home to four resident species of Macaw: The Blue and Yellow (*Ara ararauna*), the Blue-throated (*Ara glaucogularis)*, the Chestnut Fronted Macaw (*Ara severa*) and the Golden Collared (*Ara auricollis*). The Red-shouldered (*Diopsittaca nobilis*) and the Red and Green (*Ara chloroptera*) are two species of seasonal visitor macaws (Web, 1). Despite its diversity of colourful macaws, the reserve's name, Barba Azul, means 'Blue Beard' after the colloquial name for its population of *Ara glaucogularis* (Plotkin, R.L. and Riding, S., 2011). It is the only protected nature reserve set up specifically for the protection of the wild population of the remaining *Ara glaucogularis* (BA website, 2016).

Ara glaucogularis are listed as a critically endangered species by the IUCN[2] (IUCN1, 2016). There are estimated to be less than 200 in the wild and even fewer mature breeding pairs (IUCN1, 2016). The *Ara glaucogularis* population is highly fragmented, with one subpopulation to the north of the town of Trinidad. This consists of approximately 160 birds, of which the majority are encompassed by the reserve, with the smaller subpopulation to the south east consisting of only 25 (Boorsma,. 2016). Currently, the area which the *Ara glaucogularis* breed does not fall within the range of the reserve (Boorsma,. 2016).

Macaws and Conservation.

The parrot family is thought to be among some of the most endangered families of bird in the world; their vibrant colours and intelligence make them highly prized pets (Clarke and de By, 2013). The illegal pet trade has proved highly damaging to many ecosystems and is a major ongoing problem

[1] A personal observation.
[2] International Union for Conservation of Nature and Natural Resources

worldwide. It is estimated that 10 billion US dollars are brought in each year via the Bolivian black market economy, surpassed only by the weapons and drugs trade (Herrera and Hennessey, 2007).

The wild bird trade is not highly monitored in the poorer areas of Bolivia, with many tourist hostels owning wild caught birds as a draw in for western guests[3]. A study carried out in 2007-2008 in Peru found 34 species of parrot being illegally traded in markets, four of which were listed as threatened by the IUCN (Herrera and Hennessey, 2007).

No *Ara glaucogularis* were mentioned in this survey, possibly due to stronger legislation being in place since Bolivia outlawed the live bird trade in 1983 (Herrera and Hennessey, 2007). However, during the 1970s, the live bird trade was thought to have been the major reason for their decline (Herrera and Hennessey, 2007). The illegal pet trade, combined with habitat destruction occurring in the ranched areas, may have strong negative effects on population sizes that may not be seen in Macaw numbers for many years to come (Fahrig, 2003). The average number of two to three eggs per clutch, the slow maturation rate and high parental investment make the population growth rate slow and vulnerable to anthropogenic effects (webpage, 5).

Efforts to reduce the population decline of the *Ara glaucogularis* have been undertaken recently by Association Armonia. This has included putting quotas on the amount of cattle that ranchers are allowed to bring through the reserve in any given year, fencing off smaller forest islands to prevent cattle from entering, allowing regeneration of the *Attalea phalerata* and the installation of nest boxes within the forest islands for the *Ara glaucogularis* (Boorsma,. 2016). In addition to these efforts, six captive bred *Ara glaucogularis* where released from Paradise Park in Cornwall into the wild population in an attempt bolster numbers in 2013 (webpage 4) (Hesse and Giles E. Duffield,. 2000). These efforts have been met with mixed success due to lack of understanding and knowledge of this bird's breeding behaviour. As a result, no nest boxes were recorded as occupied by Macaws in 2015 (Boorsma,. 2016)

[3] A personal observation.

Morphology and Feeding habits of *Ara glaucogularis* compared to *Ara ararauna*

Little is still known about *Ara glaucogularis* due the fact that, up until the 1970s, *Ara glaucogularis* was thought to be a colour morph of *Ara ararauna*(Yamashita, C. and de Barros, Y.M., 2013). A larger sympatric species with similar ecological requirements to *Ara glaucogularis* (Parr and Juniper, 2010). The breeding season for *Ara glaucogularis* is from November to March (webpage 5), however the age that these birds become independent in the wild and the level of parental care that *Ara glaucogularis* exhibit to their young compared to *Ara ararauna* is only speculated about. These two bird species are commonly found in large mixed groups when flying or roosting in trees and share many similar attributes. Long thin wings in both species, enable them to travel great distances to foraging sites (Jurgen, Del Hoyo and Sargatal, 1997). Both species also possess zycodactyle feet, which allow them to strip away the skin and husks of fruit (Jurgen, Del Hoyo and Sargatal, 1997).

Both species' heads are proportionally larger than those of other parrot species, typical of the Psittaciformes (Jurgen, Del Hoyo and Sargatal, 1997). Both *Ara ararauna* and *Ara glaucogularis* have a large, curved upper mandible and a smaller lower mandible that can move independently of the upper mandible. Enabling these species to strip the mesocarp of the *Attalea phalerata* fruit efficiently (Jurgen, Del Hoyo and Sargatal, 1997). They also inhabit the same roosting areas in the Benni. Combined with their similar colouration and calls, to the untrained eye it would be easy to mistake them for the same species[4].

The differences between *Ara ararauna* and *Ara glaucogularis* can be subtle. *Ara ararauna* is larger and of a darker blue, with a black patch beneath their throat. *Ara glaucogularis* is comparatively smaller and with a brighter, turquoise colouration and a blue patch beneath their throat (webpage 2).

The two species are thought to have slightly different feeding habits that can be distinguished by the different markings left on the *Attalea phalerata* nuts they feed on. *Ara ararauna*, with their larger beaks,

[4] A personal observation.

leave long, horizontal scrapings when stripping the mesocarp of nuts whereas *Ara glaucogularis* leave spiral scrapings [3.] It has been hypothesised that *Ara ararauna* are more generalist feeders whereas the *Ara glaucogularis* are specialised, eating only *Attalea phalerata* nuts resulting in the different markings (Yamashita, C. and de Barros, Y.M., 2013).

Ripe *Attalea phalerata* palm nuts on average range from 6cm to 9cm (range of sizes seen in figure 10). Should *Ara glaucogularis* eat smaller fruits it is thought that the species would produce similar mesocarp markings to *Ara ararauna* (Yamashita, C. and de Barros, Y.M., 2013). However, this was not verified, as *Ara glaucogularis* were seen feeding on smaller fruits, such as those from the Arecaceae tree, in the East of the reserve (see figure 3). However, the largest difference between the two species could be seen as their their IUCN listing. *Ara ararauna* is listed as 'least concerned' and are distributed more widely throughout South America (see figure 1). Whereas *Ara glaucogularis*, residing solely within the Benni savannah (see figure 2) have 'critically endangered' status (IUCN1, 2016; IUCN2, 2016). Though *Ara ararauna* are not themselves endangered it is important to study them in conjunction with *Ara glaucogularis*, as these species have similar ecological requirements, factors that affect one species, such as the illegal pet trade and habitat degradation, are likely to impact up the other species as well (Fahrig, L., 2003).

Figure 1 map showing range of *Ara ararauna* (IUCN2, webpage)

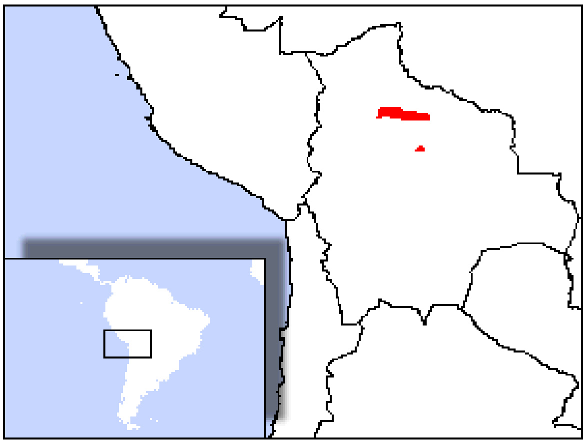

Figure 2. Map showing range of *Ara glaucogularis*, (IUCN1, webpage)

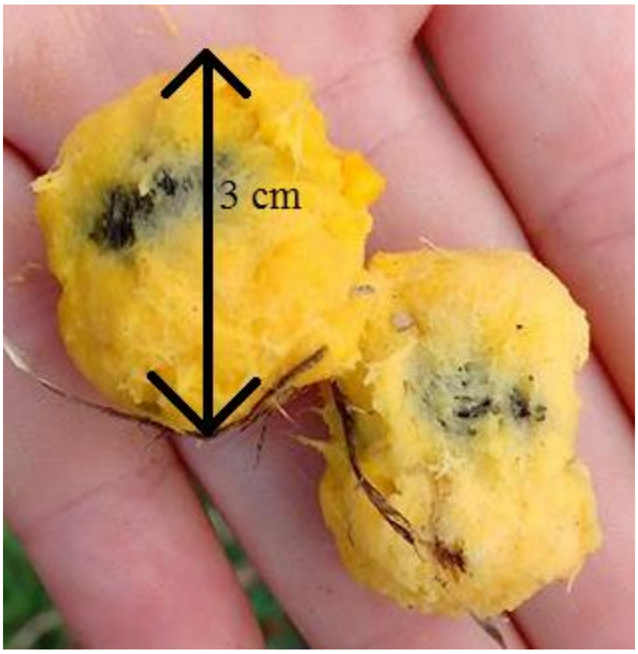

Figure 3 Image of smaller fruits from the Arecaceae tree, with associated markings left by the *Ara glaucogularis*. No long, horizontal scrapings left. Nuts ranged from sizes 3-4cm^2.

Aims

Like many tropical bird species, there much is still unknown about even the most basic behaviours and requirements of *Ara glaucogularis* (Burgess et al., 2009). Even the main predation risks and causes of chick mortality of this species are largely speculation and not categorically proved. Changing group size was looked into as other studies have found that some temperate bird species can be found in larger flocks when feeding as this reduces individual predation risk (Siegfried and Underhill, 1975), however it was unknown whether *Ara glaucogularis* group size fluctuated or stayed constant throughout the day. The aim of this research was to gain a better understanding of the feeding ecology of the Macaws and their food resource on the reserve. This was achieved through looking at food availability for the Macaws, the information for which was collated through vegetation surveys.

Canopy cover was looked into in this study as other papers in tropical regions have found that that type of vegetation present and the density of the canopy layer has affected the type of species found to forage in specific areas (Gil-Tena, A., et al., 2007). So it was a point of interest to see if there was a notable difference in feeding being carried out by vertebrate species across different areas of the reserve. With a focus on whether canopy cover affected the foraging levels carried out by *Ara glaucogularis.* As this could have a long term impact on land use management implemented by Armonia on Barba Azul.

The inter-specific and intra-specific competition Macaws face surrounding the *Attalea phalerata* was analysed via comparative behavioural studies of when the birds were not feeding. This was thought necessary because, in studies on temperate birds at least, competition had been noted as having an effect on the breeding success and population density of some species (Minot, 1981). The idea was also ventured by previous studies that competition with the larger *Ara ararauna* could be a contributing factor in the ongoing decline of *Ara glaucogularis* (Hesse, 2000).

Research was also undertaken into the physical differences in the ways *Ara glaucogularis* consumed the mesocarp of the *Attalea phalerata* nut and the time taken to eat the mesocarp by Macaw species on the reserve to see how efficient they were at utilising this food resource. This was because of some recent doubt over whether the markings used to determine a feeding site were effective as indicators of species which fed there or not.

Hypotheses :

1. Canopy cover affects the type of vertebrate species found feeding in an area.
2. *Ara glaucogularis* and *Ara ararauna* Group size differs depending on activity.
3. *Ara glaucogularis* and *Ara ararauna* do not leave different markings on the *Attalea phalerata* nut after feeding.
4. There is more interspecific aggression between Macaw species on the reserve than intraspecific aggression when Macaws feed.

Methods

A key skill necessary for this project was being able to identify *Ara ararauna* and *Ara glaucogularis* in the wild. To do this involved identifying key distinctive features including size. *Ara ararauna* are larger than the *Ara glaucogularis*, with the adult *Ara ararauna* between 86 – 91 centimetres in length from the tip of the head to the tip of the tail, making them one of the largest parrots in the world. They have a wing span of 104 to 114cm and weigh between 900 and 1300 grams (webpage 6). *Ara glaucogularis* is about 85 cm long including the length of its tail feathers and has a wingspan of approximately 0.9 m. It weighs about 900 g to 1,100 g (webpage 5).

Colouration was also used to tell the two species apart. *Ara ararauna* are darker blue on their back, and have a black patch under their beak, giving them the colloquial name 'Barba Negra'[5] (webpage 6). They also have a larger, more prominent area of white on their face around the cheek. In contrast, *Ara glaucogularis* are a lighter turquoise colour on their backs, with a blue patch on their throat and less prominent white on their face (webpage 5).

Figure 4. Photo of wild *Ara glaucogularis* (Left) on branch next to wild *Ara ararauna* (Right), showing difference in size and markings (Photo by Eleanor Collinson)

[5] 'Black beard'.

Fig.4 shows *Ara glaucogularis* on the left compared to an *Ara ararauna* on the right as seen from below in the field. The photo reveals the prominent white facial patch, black throat patch and larger size of the *Ara ararauna* compared to *Ara glaucogularis*, which is smaller in size and lacks an obvious white facial patch.

Macaw species could not always be told apart in the wild by visual observations alone, if they were in flight for example. Calls were also used to aid identification: *Ara glaucogularis* had a higher pitched call than *Ara ararauna* which had a raspier sounding call[6].

Locating sites

Teams of two, if carrying out a morning survey, would set out walking slowly (approximately. 3 mph, the average human walking speed) as the terrain was uneven, between 7am and 8am in the morning depending on the distance to the sites, which ranged between 50 metres from camp (closest) to approximately 2 miles from camp (furthest site). Return to the camp was by 11:30am[7]. If the survey was on an afternoon, the team would set off between 2:30pm and 3pm, again site dependant, walking at a slow pace, either through the forest islands or along the outside edges of the islands down the cerrado and surrounding marsh, listening for calls of the Macaws. Once heard, the teams would head in the direction of the sound. Teams would not walk in transects to try and find sites, as previous studies found this method ineffective for locating feeding sites (Macdonald, 2012).

To identify areas where *Ara glaucogularis* could be found, a few days were spent searching for feeding sites in the afternoon at 2pm. This time of day was chosen because the birds are active throughout the day but fly back to the roost site at night. Consequently, signs such as feathers and fallen nuts had often been trampled or moved by the activity of other forest-dwelling species during the night, meaning morning surveys were not as successful.

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[6] Personal observation

[7] Though Macaw species are found to be most active between the hours of 10am and 2pm (Macdonald,. 2012) surveys were not able to be carried out during a large proportion of these hours due to external factors such as the temperature during these hours.

Physical signs of the Macaws having visited the area included findings such as dropped feathers of the two species -which could be told apart by colouration and size - *Ara glaucogularis* feathers being turquoise in appearance and *Ara ararauna* being a darker blue.

Freshly eaten nuts were used to determine if Macaws were in the area. The age of the nut could be told by the colouration of the mesocarp. Yellow or orange meant it had been very recently eaten, and white or brown meant it was old and not a good indicator of recent activity (see figure 5) (Yamashita, C. and de Barros, Y.M., 2013). Old nuts could also be misleading as the nuts themselves had long marks across them which could be mistaken for a marking left by a Macaw if the observer wasn't careful, so in general these were discarded[6]. Figure 6, 7 and 8 show fresh nuts, as indicated by the orange colouration previously mentioned, which have been consumed by the species that were investigated and the associated markings.

Figure 5 Photo of two Motacu Palm nuts that would have been discarded for being too old to accurately identify markings. (Photo by Eleanor Collinson)

If fallen nuts were located, the bushel they had come from would be looked for. If the bushel was finished, it was unlikely Macaws would return to the area in the near future[6]. However, if there was a part-eaten bushel nearby, or bushels near a newly finished nut, then a GPS mark would be taken of the area as it was noted that Macaws would often return to the same sites frequently over the course of the coming days, until all the ripe *Attalea phalerata* nuts had been consumed[8]. No Golden-collared Macaw markings were identified.

[8] Personal observation.

Figure 6 4 (top left). Notice the wide scrapings, accepted as left by *Alouatta Caraya* as the grooves are wide. (Photo by Eleanor Collinson)

Figure 7. Markings left by *Ara glaucogularis* before final spiralling was undertaken. (Photo by Eleanor Collinson)

Figure 8. Markings left by *Ara ararauna*. Notice the long, vertical lines left by beak down the length of the nut. (Photo by Eleanor Collinson)

Figure 9. Markings left by a ground-foraging mammal (likely *Sus scrofa domesticus*) (photo by Eleanor Collinson)

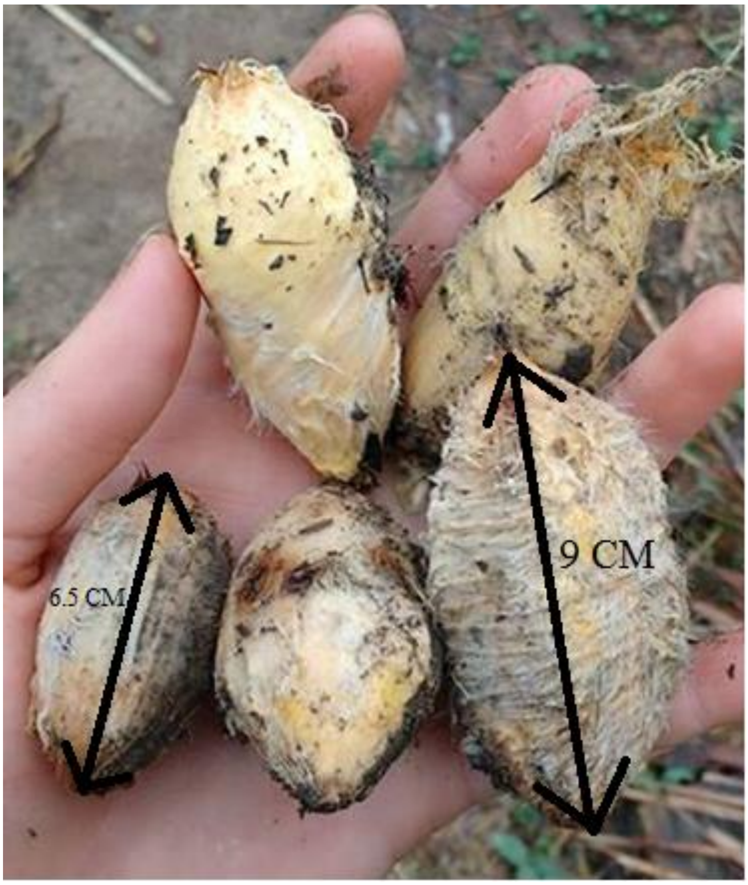


Figure 10. Top 2 and bottom right (largest nut 9cm) in photo depict marks left by *Ara glaucogularis*. Bottom centre and bottom left (smallest 6.5cm) depict markings left by *Ara ararauna*. Size of nuts ranged from 6.5cm to 9cm (photo by Eleanor Collinson).

Behaviour

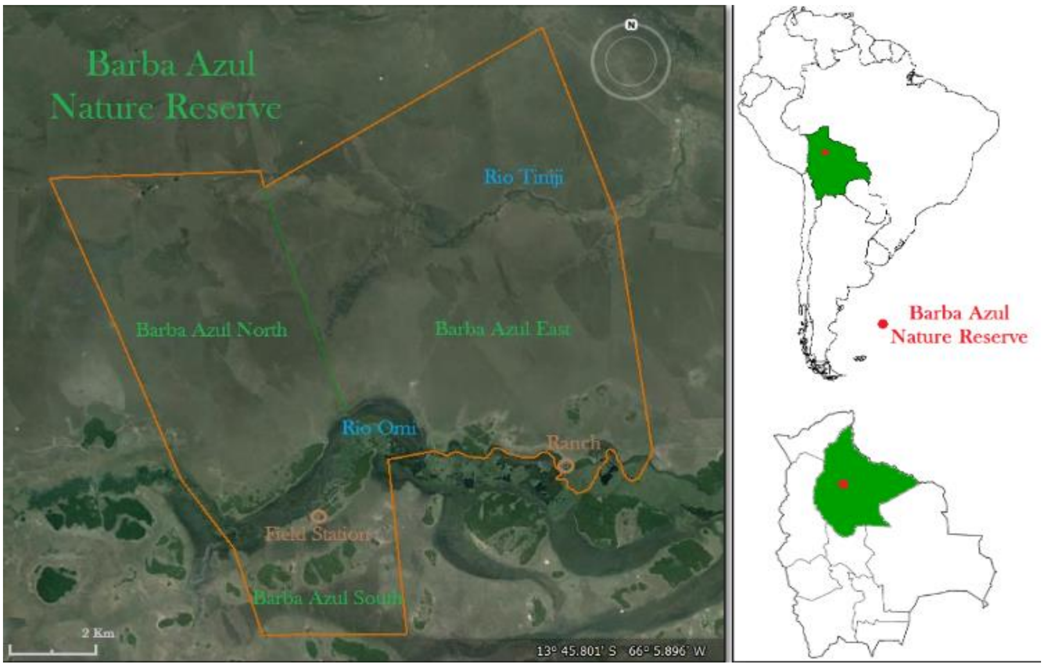


Figure 11 Showing map of Barba Azul Reserve and it's location within Bolivia (Amonia,. 2016).

This study was carried out in pairs. Three hours were allocated in either the morning or the afternoon, starting from 8-11am or 3-6pm. Exact start time depended on site distance from camp. The heat of midday meant no work was able to be carried out between 11:30am and 2:30pm. Three sites were picked per day that were in close proximity to one another, allowing fifteen minutes' walking time to get from one site to the next. 45 minutes' observation time was then taken at each, adding up to a total of an hour allocated to each site. This process was carried out once a day, four times a week for eight weeks. Sites were pre-chosen before heading out.

This was not done through random selection as it was noticed that at certain times of the day the majority of the birds could more often than not be found in certain sections of the island, so it was decided to go to sites known to be frequented at certain times of the day. For example, in the afternoon a very large mixed group of *Ara ararauna* and *Ara glaucogularis* would group together on the tip of the island before flying to the roost at around 6pm. So, if afternoon observations were occurring, they would include this site as it reliably produced data.

If, while walking to chosen site, a group of *Ara glaucogularis* were spotted, it was decided that the observers should stop, make a note of time and location and begin observations from the point where the macaws were spotted from, instead of the pre-set site. This was because there were so few *Ara glaucogularis* present on the reserve, it was very unlikely that multiple groups would be located in the 3 hours allocated (IUCN1 webpage).

If, upon arriving at a site, the observer's presence scared off all the Macaws from that area, the adopted protocol was to move quietly to a site nearby in the direction the birds flew in and carry out observations from the new site instead, pausing the time set for observations from the time the birds flew off, and running the rest of the observation time in the next spot. This was done because the Macaws did not often return to the same site within 45 minutes having been spooked, and when flying off they would sound loud alarm calls causing all other birds in the area to leave at the same time.

If an area was reached without scaring off the Macaws, or if there were no birds in the area at that time, the observers would set up in a position slightly apart from each other in order to be able to see a wider section of the tree canopy. Each site was roughly 25 metres in diameter, and observation points within the sites were chosen to provide the best view of any birds that flew into the area. The *Cecropia* trees on the fringes of the forest islands tended to give the best view, as they did not have thick foliage and the branches were spaced apart from each other meaning it was easy to see a perching bird, unlike the *Attalea phalerata*, where the leaves of would often completely obscure an arriving bird from view.

It was also found that the Macaws did not often eat a nut on the bushel it originated from, but would carry it off in their beak and gather in the *Cecropia* trees with a larger group towards the edge of the forest. For that reason, many observations were carried out from the marsh surrounding the forest islands rather than within the islands themselves.

45 minutes were spent at each site, waiting for Macaws and recording their activity before moving on to the next site. The data were recorded on a Panasonic hand held video camera with a x75 zoom, placed upon a tripod, which the observers carried with them, meaning the birds could be recorded without getting too close. This was helpful as it was noted that the birds would often fly off, sounding alarm calls if the observer got within a 20m distance of the tree they were perching in. The person with the video camera would focus in on the activity of one or two individual birds, whereas the other observer would be using binoculars and noting down the activity of the larger groups of Macaws and their dynamics, and alerting the observer filming if they noticed a bird displaying interesting behaviour in a different section of the tree.

If birds flew into the area the relevant information to be tabulated was: -

1. Time the birds arrived and the time that group left.

2. The group size.

3. Behaviour exhibited, such as preening, allopreening, playing, play fighting, fighting, feeding.

Specified behaviour	Detailed description/definition.
Perching	Resting on the branch of a tree, relatively little movement/activity, inactive
Allopreening	Grooming another individual
Autopreening	Self-grooming
Foraging	Picking off and consuming strips of bark, leaves and berries from tree canopy. Removing *A. phalerata* palm nuts from husk and consuming mesocarp of nut.
Play fighting	Pecking, bill fencing, squawking calls, wing flaps etc. between individuals in a non-aggressive way.
Aggressive fighting	Interactions between individuals in an unfriendly/aggressive manner (usually in relation to dominance hierarchy)- squawks, pecking, one submitting to the other.
Regurgitation	The adult bird of one species of macaw bringing up food into the mouth of a juvenile macaw.
Flying	Birds flying overhead but not landing in the tree canopy.

Table 1. Ethogram of Macaw behaviour recorded. (Adapted from Macdonald,. 2012).

If feeding behaviour was observed, then how many out of the group were feeding and what they were feeding on was recorded. Any interesting observations regarding behaviour, especially feeding and aggressive behaviour, were recorded in a table such as table 2 below:

Table 2. Table showing the way behaviours were recorded and noted down in the field. BY is an abbreviation of 'Blue and Yellow Macaw'.

Site	Date	Species	Group Size	Time Arrived	Time Left	Behaviour
15	12/07/16	BY	2	08:05	08:05	Flying

Vegetation survey

This survey was testing the more classical method of identifying feeding sites of *Ara glaucogularis* from the markings left upon the nuts. The amount of food available to *Ara glaucogularis* was assessed by looking at what percentage of the *Attalea phalerata* had fruit that was ripe-enough to be eaten (fruiting *Attalea phalerata* depicted in figure 12) by the Macaws, and how well *Ara glaucogularis* were competing with other species on the reserve for this food source. The percentage of nuts eaten by *Ara glaucogularis* compared to other species was deduced by observing the markings left on the fruits. Concurrently, a survey was carried out to help locate areas suitable to place a camera trap.

Figure 12 *Attalae phalerata* with ripe bushel (webpage 8)

This method required one scribe and one GPS receiver. The forest islands were divided up into areas of roughly $200M^2$ to minimise the risk of trees being counted twice by two separate vegetation surveys. A pre-decided area was randomly selected by drawing site numbers from a hat and removing that site from the hat once picked, ensuring each site was sampled at least once. Two observers would walk around within the selected area until a fruiting *Attalea phalerata* was found. Once a fruiting tree within that area was located, the tree was GPS marked. The tree was labelled Gps1 and TF (1) (see table 3).

While the GPS point was taken, the scribe estimated the canopy cover directly surrounding the bushel by pressing thumbs and forefingers together to make a window and looking through it up at the canopy. The percentage of canopy cover was calibrated for different members of the team by drawing a quadrat on a piece of paper and shading in 10%, 20%,25%,30%, 35% and so on up to 100%, so observers had a relatable measure of what percentage canopy was covered by leaves when looking up.

The percentage of sky covered by the canopy was noted in the %CC column[9]. If more than one bushel was found on a tree, percentage canopy cover was estimated for each bushel individually (seen in the written in example table 3 below). However, as it was impossible to say for certain, if there was fallen fruit beneath the tree, which nuts fell from which bushel, the rest of the survey was done for the tree as a whole and not for each individual bushel.

After marking down the GPS, tree numbers, and degree of canopy cover, the forest floor in a 3m radius around the trunk of the tree was inspected for fallen nuts, as this indicated whether the bushel was ripe. 3m was chosen as the perimeter surrounding the tree as it was noticed that, in a group of trees, this was the furthest distance where it could be said with any certainty that the fallen nut had come from the tree being recorded, and not another in the surrounding area. If freshly fallen nuts were found on the ground, a note was taken of how many nuts out of the total amount of fallen nuts were eaten by the species being investigated. These species were: *Ara glaucogularis*, *Ara ararauna*, *Alouatta Caraya* and then 'other' animals.

The nuts were identified by looking at the markings left on the nut. If long, broad vertical scrapes were found, it was labelled as a *Ara ararauna*. If there were either spiral, corkscrew shaped markings or a half vertical, half horizontal effect, then it was labelled as *Ara glaucogularis*. If there were messier, wider spiral markings it was labelled as *Alouatta Caraya*, and if it was frayed and had no clearly defined markings the nut was put under the bracket 'other', meaning left by *Sus scrofa domesticus*, *Pecari tajacu*,, agouti (*Dasyprocta punctata*)[10] or other ground-foraging species or opportunistic song birds that were occasionally seen feeding on the fruit of nuts that had been discarded by Macaws. The 'other' column was to cover all ground foraging animals and opportunistic bird and rodent species that are not in direct competition with *Ara glaucogularis* for this food resource.

[9] ' Or 'Percentage Canopy Cover'

[10] These markings are similar to squirrel and other species markings left on pine cones in the UK, with clear gouges left by large front teeth.

If nuts could not be identified, they were discarded so all numbers recorded were the minimum number each species on the reserve could have consumed, and not the maximum. If no fallen nuts were found, this would indicate that the bushel was not ripe and so a score was made through the rest of the columns.

Once row 1 had been completed for a tree, a marker was left on the path and the observers walked in a straight line forwards, counting immediately to the left and right the 50 nearest *Attalea phalerata* to the transect. Whenever a *Attalea phalerata* with a bushel was observed, the observers would stop and repeat the process carried out for tree no.1. Once 50 *Attalea phalerata* had been counted, the observers stopped and walked back to original tree (GPS marked) and repeated the process in the opposite direction. The aim was to count 100 *Attalea phalerata* each time. However, if 100 *Attalea phalerata*s could not be counted (due to the size of the island being too small or the size of the *Attalea phalerata* stand) a note of how many trees had been counted was made so that the percentage of fruiting trees could still be calculated.

Table 3 Showing how vegetation data was recorded in the field.

Date	GPS	No.TF	%CC	FN?	BTM	BY	HOW	OTHER	TOTAL
02/05/16	C15	1	90	N	/				
"	C16	21	(75)(60)	N	/				
"	C17	49	35	Y	5	17	0	19	41

Camera trap

Whilst Camera traps were set up, the data recorded ended up not being suitable for this project. More details on how they were set up for future projects can be found in the appendix.

Data Analysis

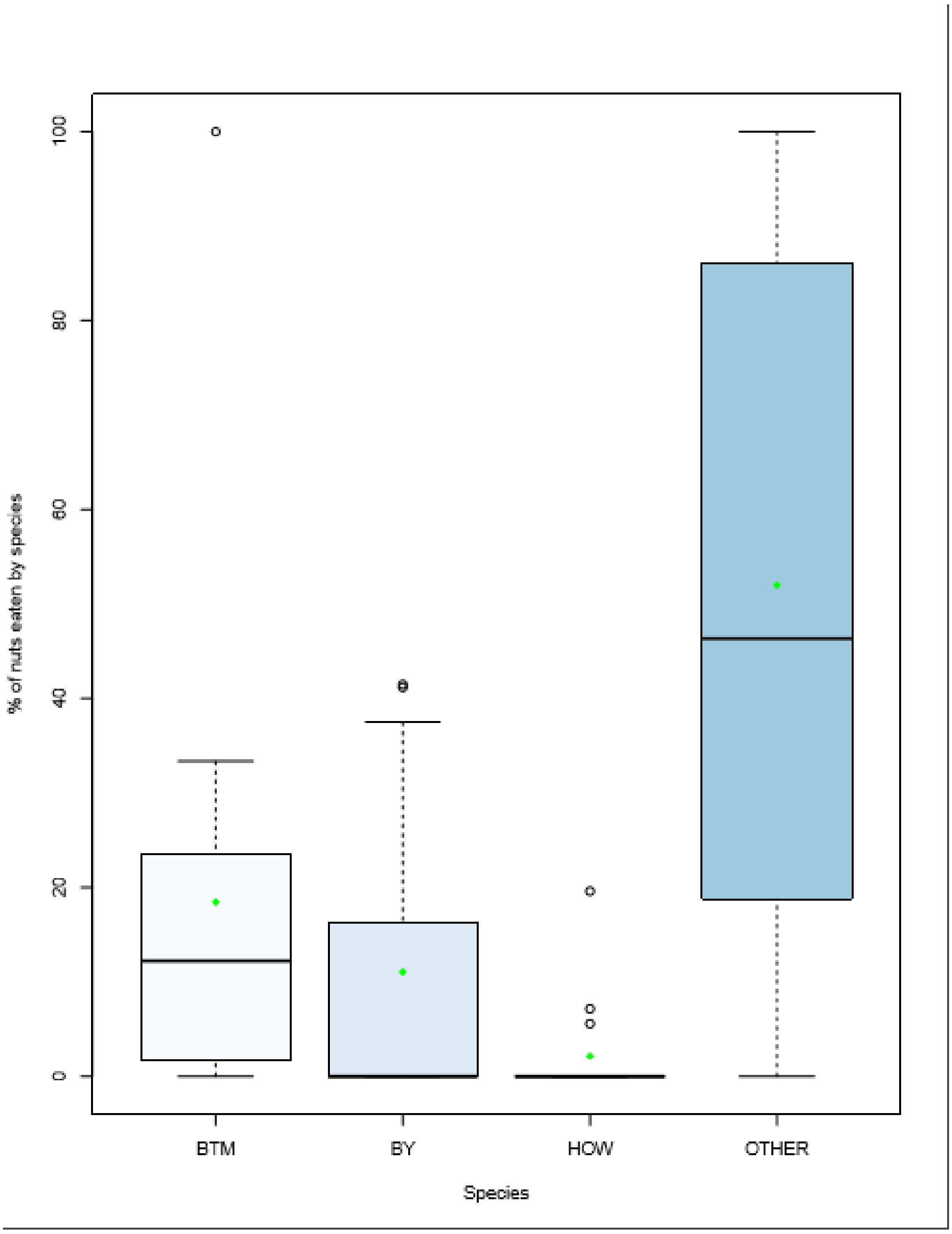
The data recorded by hand in the field note books was typed up into corresponding tables in excel (An example of one of these data sheets can be found in the appendix). The video data recorded was played back to analyse behavioural observations. Simple tables were created in excel. These tables were filled in by turning behavioural observations into numerical data. For example, every time an aggressive interaction was recorded it was labelled as '0' where as a none aggressive interaction was labelled as '1' allowing for statistical analysis to be carried out on the qualitative data. Species were denoted as either ‘A’ (*Ara ararauna)*, ‘B’(*Ara glaucogularis*)or ‘AB’ to show whether the interaction was intraspecific or interspecific (Figure 20, appendix).

Rstudio was used for statistical analysis. GLM models were run on the vegetation surveys, group size and activity analysis, and also when comparing intra-specific and inter-specific aggression surrounding food availability(figures 13,14,15,16, 18,19). A negative binomial model was run on count data to test whether there was a difference in average feeding group size compared to non-feeding group size (figure 17). Chi squared tests were carried out to test whether the two species of Macaw ate in mixed species groups and, when looking at the method used to scrape the mesocarp from the nut, whether a spiral, straight or mixed technique was employed (tables 4 and 5). Results were presented using a range of boxplots, scatter plots, tables and a frequency histogram created on RStudio and excel.

Results

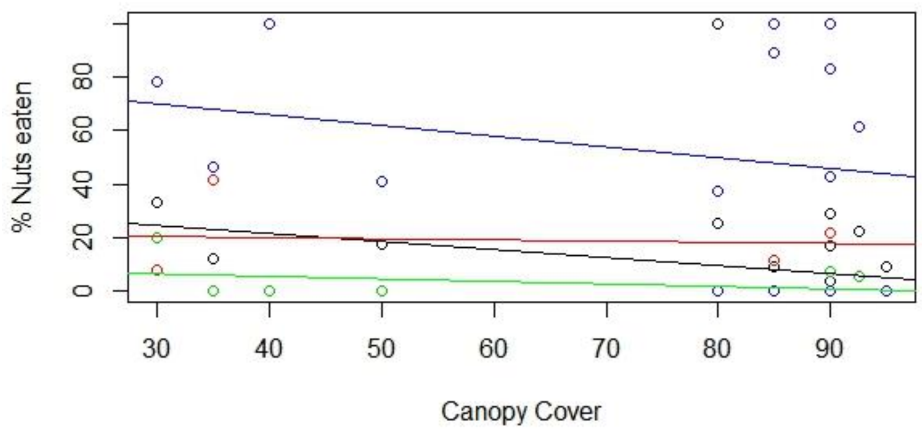
Vegetation Data: Looking into effect of canopy cover (hypothesis 1)

Figure 13 showing different proportions of *Attalea phalerata* nut consumed by different species on the reserve. The thick band in the middle denotes the median. The space on either side of the line within the box denote the upper quartile (above the line, with the top of the box relating to the 75th percentil) and lower quartile (below the line, with the bottom of the box relating to the 25th. The outlying circles correspond to extreme outliers within the data for each separate Species. (*Ara glaucogularis*: BTM, *Ara ararauna*: BY, *Alouatta caraya*: HOW, ground foraging species: OTHER)



The GLM analysis of figure 13 showed that the type of species foraging had a significant effect on the proportion of nuts consumed (P value= 4.999e-06, F= 11.62, DF = 3).

Figure 14 is a frequency scatter plot showing the relationship between canopy cover and proportion of nuts consumed by each species. Colours correlate to separate species, circles are individual data points, lines across the graph denote the linear regression lines for each species data set. ***Ara ararauna*** **=Black,** ***Alouatta caraya*** **=Green, Other=Blue,** ***Ara glaucogularis*** **= Red**



Anova models for figure 14 showed that Canopy Cover did not have a significant effect on the percentage of nuts eaten (P value= 0.149 and F = 2.143). However, species was found to have a significant effect, (P value= 4.24e-06, F=11.861 on 4 degrees of freedom).

Behavioural study: Looking into Group size dynamics (hypothesis 2)

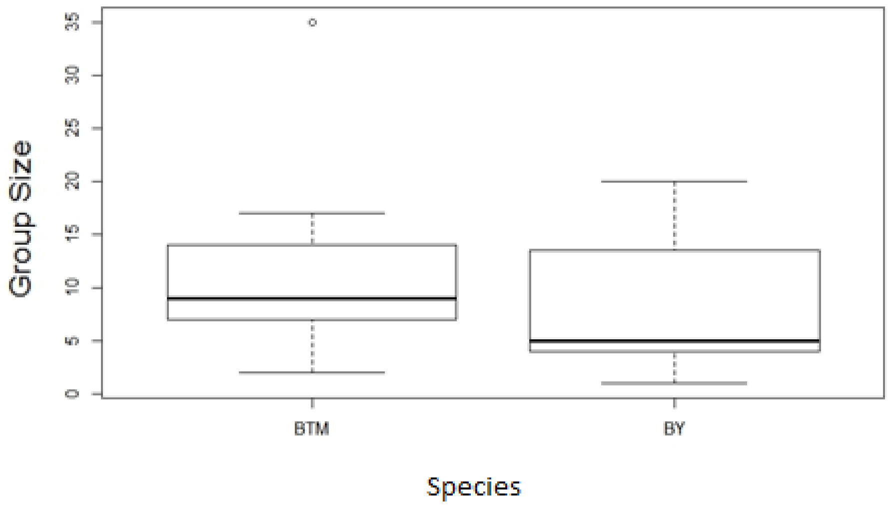


Figure 15. Graph showing average feeding group size between *Ara glaucogularis* and *Ara ararauna* The box denoting the interquartile range, which encompasses 50% of the data points . The thick band in the middle denotes the median. The space on either side of the line within the box denote the upper quartile (above the line, with the top of the box relating to the 75th percentil) and lower quartile (below the line, with the bottom of the box relating to the 25th percentile). The whiskers encompass the data points that fall outside of the 50% for each species and the spread of data around the interquartile range and the bottom of the whisker relating to the lowest value recorded.

The GLM model for figure 15 did not generate a significant result (P=0.358023. DF=19). Species did not have a significant effect on feeding group size of Macaw species.

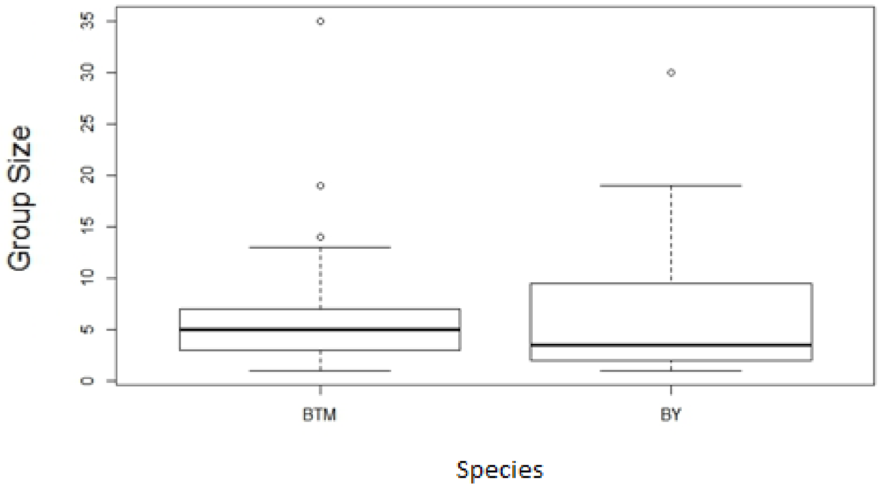


Figure 16 Average group size showing difference between none feeding group size of *Ara ararauna* compared to *Ara glaucogularis*. Details on the box plot equate to the same as for figure 14 with the addition of dots above the whiskers denoting the extreme outlying data points.

GLM analysis for figure 16 generated a significant effect (DF=67, p=0.763). No significant effect from species found in none feeding group size between Macaw species.

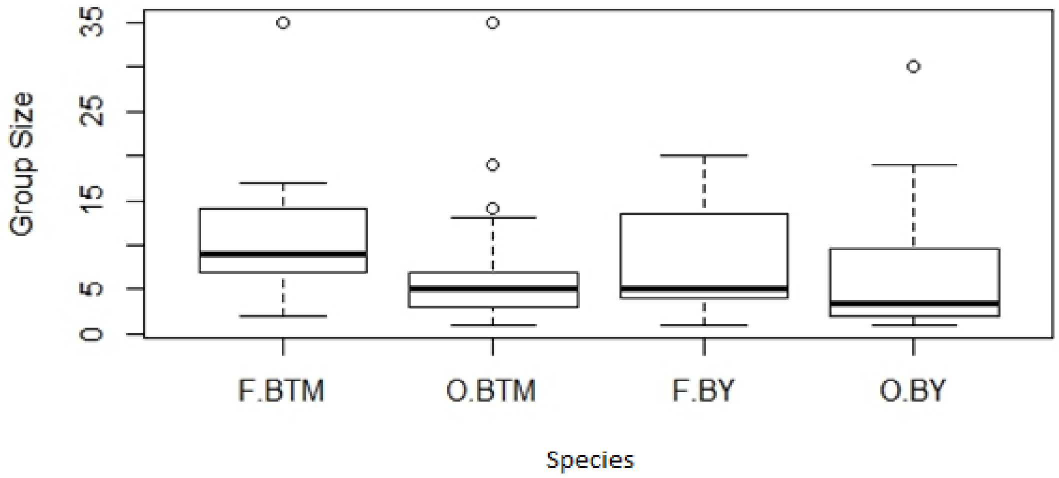


Figure 17 Box plot showing difference between feeding and none feeding group size for both Macaw species. F.BTM meaning Feeding *Ara glaucogularis*, O.BTM meaning group size for non-feeding *Ara glaucogularis*. F.BY meaning Feeding *Ara ararauna* and O.BY for non-feed *Ara ararauna.*

Shapiro - Wilk normality test was used for count data figure 17. Species did not have a significant effect on group size (p=0.435). A significant effect was found within group size depending on if Macaws were feeding or carrying out another activity (p-value = 4.85×10^{-4}, DF= 4)

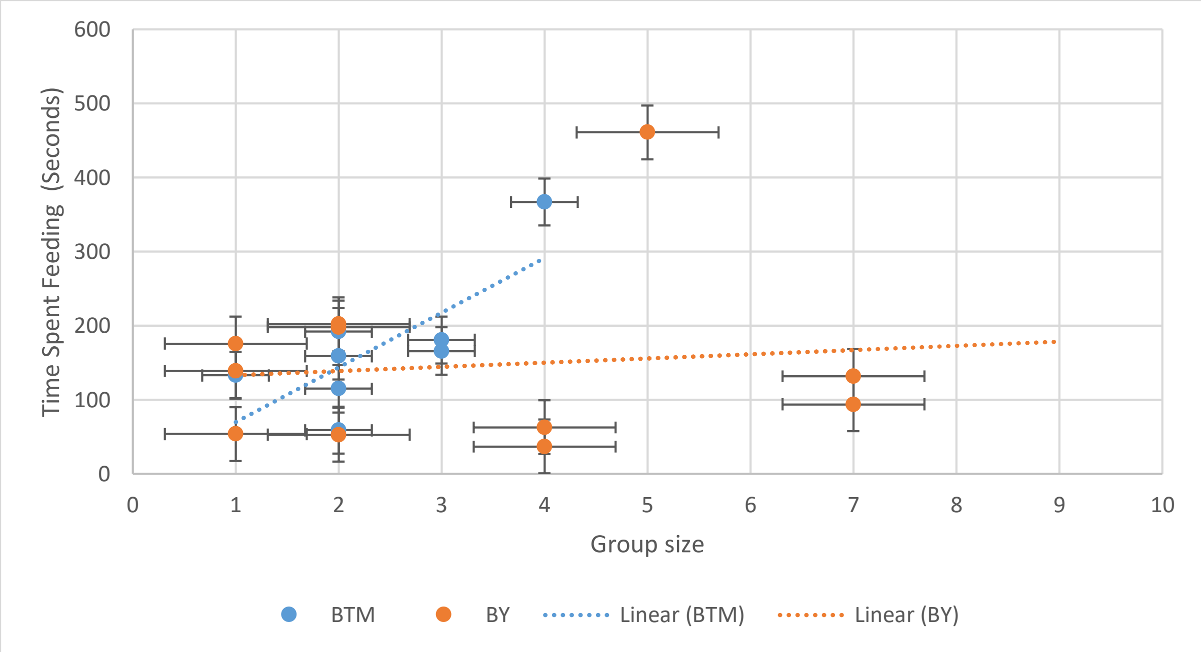


Figure 18 Scatter plot showing how time spent feeding varied with Group Size for *Ara ararauna* (BY) and *Ara glaucogularis* (BTM). The lines around the points are error bars for each individual data point. The linear regression lines denote the overall trend when combining the individual data points.

GLM models revealed that group size does not significantly affect time spent feeding by individuals o f either species (P=0.3948) as demonstrated in figure 18.

Aggression: Looking into Competition surrounding the food resource and the physical way in which Macaws eat the nut (hypothesis 3 and 4).

Table 4 showing how many times different Macaw species were recorded eating the *Attalea phalerata* nut and employing different techniques to strip away the mesocarp, Horizontal was the sideways spiral effect assosciated with *Ara glaucogularis* where as vertical gave way to the marking classically attributed to *Ara ararauna*. 'Mixed' column was the new type of marking attributed to *Ara glaucogularis*.

	Horizontal	Vertical	Mixed	Total
BTM	1	4	7	12
BY	0	10	1	8
Total	1	14	8	23

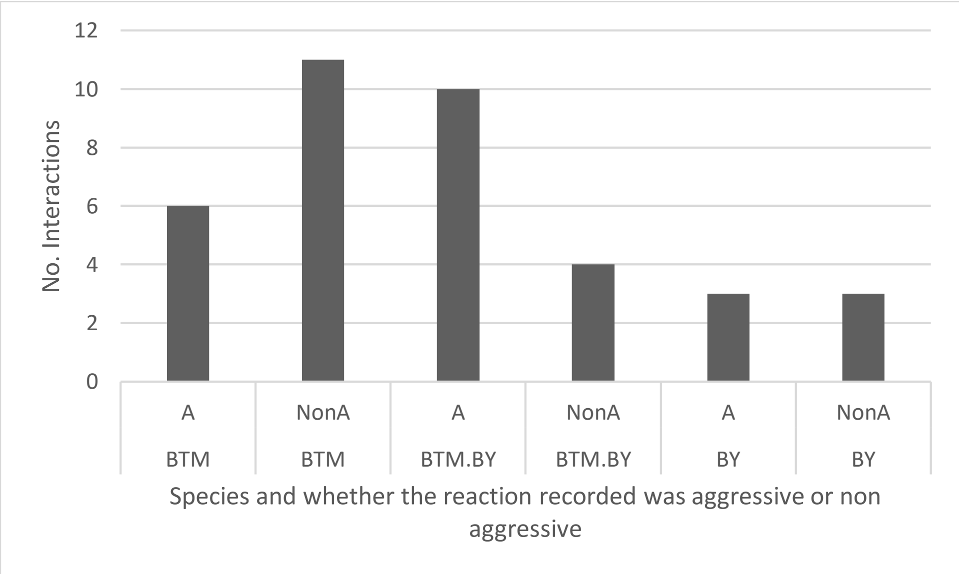
A Chi squared test was carried out. A significant result (10.5082 was generated, DF=2. P value= $5.227x10^{-3}$). Null hypothesis 3, that species eat the same way generating the same markings, was rejected.

Table 5. A Chi squared test was also carried out looking at whether the macaw species ate in mixed species groups where *Ara glaucogularis* and *Ara ararauna* were recorded feeding at the same time in very close proximity, or recording the amount of times Macaws were seen feeding solely in close proximity to members of their own species. Null hypothesis: Macaws eat equal amounts in mixed and same species groups.

	BTM	BY	TOTAL
MIXED GROUP	7	10	17
SEPARATE GROUP	20	2	22
TOTAL	27	12	39

Chi squared analysis of Table 5 revealed a significant difference (X-squared = 10.364, DF = 1 p-value = $1.572x10^{-2))}$. Null hypothesis that Macaws eat equally in mixed species and same species groups is r ejected. Results showed Macaws eat in same species groups significantly more often than mixed speci es groups.

Figure 19 Frequency histogram showing amount of inter and intra specific aggression recorded when feeding. The middle two columns contain the data for the amount of times Macaws were recorded in mixed species groups. The first two columns denote a feeding group comprised solely of *Ara glaucogularis*. The Last two columns denote feeding groups comprised solely of *Ara ararauna*. A=Aggressive , NonA= Non aggressive interaction. BTM (Blue-Throated Macaw) BY (*Ara ararauna*) Intra specific. BTM.BY (*Ara glaucogularis* vs *Ara ararauna*, interspecific).



GLM analysis of figure 19 generated significant results for interspecific aggression (P value = 0.0266, DF= 38), however it did not generate a significant value for intraspecific aggression (P= 0.4691, DF= 38).

Discussion

In order to better understand the feeding ecology of *Ara glaucogularis,* an effort was made to look at a broad range of interconnecting biotic and abiotic factors and behaviours, surrounding their primary food resource the *Attalea phalerata* nut. This was done to try and gain a better understanding of the species as a whole.

Vegetation surveys (Hypothesis 1)

There was found to be a significant difference in amount of feeding carried out by different species on the reserve (as seen in figure 13). Figure 13 also seemed to indicate that the vast majority of *Attalea phalerata* nuts were being consumed by ground-foraging animals, closely followed by *Ara glaucogularis.* The ground-foraging animal result was expected due to the high number of escaped domestic pigs (*Sus scrofa domesticus*) on the reserve[11], and the fact many mammal species are active during the day and the night (Halle, S., 2000) whereas Macaw species were only actively foraging during the day (Macdonald, 2012). Also the fact that, as it was measuring indirect competition and not direct competition, multiple species were included in the 'other' plot. Whereas the rest of the plots in figure 13 each related to a separate species. This factor likely had a large influence on why the 'other' column had such a higher proportion of the nuts compared to the rest of the dataset. It could be a worthwhile future study to look into the competition between ground foraging species, if the individual markings can be identified. However, that *Ara glaucogularis* were recorded as eating more *Attalea phalerata* nuts than *Ara ararauna* was unexpected, due to considerably larger population of *Ara ararauna* on the reserve (BA website,. 2016).

This result could be due to *Ara ararauna* being a more generalist species (Yamashita, C. and de Barros, Y.M., 2013), so may rely less heavily on the *Attalea phalerata* for food and could be supplementing their diet in other ways. *Ara glaucogularis,* however, is an *Attalea phalerata* specialist (Yamashita, C.

[11] From observations made by reserve manager Tjalle Boorsma.

and de Barros, Y.M., 2013). Perhaps because *Attalea phalerata* produce fruit all year round (Hesse, 2000) which could have, over time, led to the non-migratory *Ara glaucogularis* becoming dependant on these palms as a food source. It could also be that *Ara ararauna* are found more evenly spread throughout the reserve. This is demonstrated by the fact that two observation sites happened to be dominated by a group of 13 *Ara glaucogularis* that habitually returned to the area to feed[9]. Whereas groups of *Ara ararauna* appeared more evenly distributed throughout the reserve[12]. However, more research into territorial behaviour would be needed to establish whether this is indeed the case.

There is a possibility that some misidentification of the nuts was taking place. On less straight nuts, *Ara araraunas* long diagonal scrapings patterns looked to be more spiral in formation. However, this effect was only noticed in the East of the island not the North, and the fact it was spotted and made a note of means it is unlikely to be a variable that would affect the results significantly.

Figure 17. Scrapings of an *Ara ararauna* on a curved nut.

Identification of *Alouatta Caraya* markings was where the most uncertainty lay, meaning a lot of nuts were discarded to reduce uncertainty over which species had created the markings. This was partly to do with the fact that Macaws were seen feeding first hand, so the nuts could be collected directly after being dropped, leaving very little chance that another animal had made the markings.

Macaw groups tended to exploit a fruiting *Attalea phalerata* patch until there was no fruit left on the bushel before moving on[13]. *Alouatta Caraya*, however, were only seen feeding on camera traps so

[12] Personal observation.
[13] Personal observation.

freshly eaten nuts were not often available. No population studies on *Alouatta Caraya* have been carried out on Barba Azul, so it impossible to say if the small number of nuts bearing their markings are an indicator of a small population size of this species, or whether it was due to other factors. This could include discarded nuts being picked up and grazed upon by ground foraging species once dropped before being discovered by the researchers. Causing these nuts to be labelled in the 'other' column as original *Alouatta Caraya* markings would become distorted by this. However, a more in depth study is needed to test this theory.

Canopy cover was not found to have a significant effect on amount of feeding carried out by the different species on the reserve (as seen in figure 14). Other studies have found specialist birds, such as *Ara glaucogularis,* favour less dense canopy cover whereas more generalist species, such as *Ara ararauna,* prefer denser canopy cover (Gil-Tena, A., et al., 2007).

This difference in results could be because the forest islands within Barba Azul are quite small and uniform in plant composition (Brace et al., 1997), with even the largest island, BA island, only measuring 1368000m (Macdonald,. 2012)^{2} [14]. A limitation of this study was the fact only a short distance could be traversed each day in search of feeding sites as the only transport method the team had was by foot. Had there had been regular access to horseback or quad bikes, it is possible that a larger area could have been traversed in one day, and over the total project time. This could have meant a wider range of feeding sites could have been accessed and studied which may have had different types of fauna present. It is possible that if there had been a larger, more diverse forest study area, an affect caused by canopy cover may have been noticed. This might have provided evidence for an effect by canopy cover as noted in other studies (Gil-Tena, A., et al., 2007).

Behavioural Study (Hypothesis 2)

Group size

[14] MacDonald. Unpublished dissertation 2012.

No significant difference in group size was found between the two species of Macaws for feeding activity (see figure 15) or other activities including preening, allopreening, flying, perching, and playing (table 1, figure 16). However, it was found that, for both species, there was a significant difference between average group size when feeding, compared to when undertaking these other activities (see figure 17). This could be because the birds naturally group together when feeding as they are more vulnerable at these times, thereby reducing predation risk to the individual (Siegfried and Underhill, 1975).

Birds of prey such as the Orange Breasted Falcon (*Falco deiroleucus*), Harpy Eagle (*Harpia harpyja*) and Hawk Eagle *(Nisaetus cirrhatus)* are known to occasionally prey on *Ara ararauna* (webpage 6). *Ara glaucogularis* is preyed upon by these and more species than *Ara ararauna*, likely due to its smaller size. Great horned owls *(Bubo virginianus)*, one of which was recorded on the reserve for the first time during our stay (Boormas, N.D.), are found across the Beni savannas and are known to take *Ara glaucogularis,* but not *Ara ararauna* (webpage, 7). This extra predation risk could explain why *Ara glaucogularis* were recorded in slightly larger, though not significantly larger, groups of 6 when feeding, compared to groups of 4 *Ara ararauna* (figure 16) (Roberts, 1996). The larger group size when feeding could also explain why a larger proportion of dropped nuts were recorded as being consumed by *Ara glaucogularis,* even though there is a larger population of *Ara ararauna* on the reserve (figure 13). If *Ara glaucogularis* fed in larger groups it would be expected that there would be fewer, larger patches of dropped nuts by *Ara glaucogularis* distributed throughout the islands. If these happened to be recorded in a vegetation survey it could paint a false picture about the true proportion of nuts being consumed by this species compared to others on the reserve.

The project was limited somewhat by the times of day when research was able to be carried out. No research was able to take place between the hours of 11:30am and 2:30pm, which encompasses the time frame when Macaws are most active (Macdonald,. 2012)[15]. It is plausible that if research had been able

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[12] It was thought when looking for study areas, that the birds could be found in different areas at different at different times of the day possibly depending on shade given by the trees at that particular time, for example a very large, mixed species flock could reliably be found on the Northern tip of the main BA island between 4pm

to be carried out throughout the duration of the day differences in group size, activity dependant, may have been noticed between *Ara glaucogularis* and *Ara ararauna*. It is also possible that if a study was conducted on a broader scope of activities relating to group size, rather than just feeding group size compared to all other activities (such as preening, playing and perching), that some significant differences between *Ara glaucogularis* and *Ara ararauna* may have been identified.

Group size itself was not, however, shown to have a significant effect on time spent feeding (see figure 18). We may speculate that this could be due to the physical process of removing the shell and eating the mesocarp of nut itself, which may require a set amount of time, regardless of group size.

Physical differences in *Attalea phalerata* Nut consumption (hypothesis 3 and 4)

The Chi squared analysis in table 4 revealed that the two species of macaw consistently ate the mesocarp of the *Attalea phalerata* nut using different techniques to the other species. This result was interesting as there had been some doubt on the reserve as to whether the markings left by the Macaws were suitable evidence to determine which species had consumed the fruit[16]. The video data analysis revealed that the markings are an accurate way of identifying feeding sites as originally believed by previous studies (Yamashita, C. and de Barros, Y.M., 2013).

A new type of marking left by *Ara glaucogularis* was discovered by this survey as seen in figure 7. This was taken into account when Chi Squared analysis was run, table 4. It could be that the final stage of the process of eating the mesocarp of the nut, involving the horizontal twisting with the foot while scraping with the beak, is a difficult technique to master and takes practice to perfect the method responsible for the full spiral track marks (Yamashita, C. and de Barros, Y.M., 2013). This could potentially explain a feeding behaviour exhibited by juvenile *Ara glaucogularis,* who were observed on six separate occasions being fed by regurgitation methods by adult birds. This behaviour was unusual

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and 6pm. Many species of bird are known to have developed various behavioural and physical adaptations to cope with heat stress (Bryant, 2008) but more research need to be requires to test this theory.

[16] An observation made by Tjalle Boorsma.

for birds of this age as in all other appearances, apart from the colour of the iris (webpage 5) in appearance the juveniles were identical to the adult Macaws.

However, if this is a difficult technique to master it could be that juveniles' diets still need some supplementation by the adult birds. This feeding by regurgitation behaviour was not witnessed being carried out by *Ara ararauna*, who are larger birds, so holding and scraping the nut may be easier for the young of this species than for the young of *Ara glaucogularis* (webpage 2). The difficulty in telling adult birds apart from juveniles at this age hampered this study as it not often possible to accurately identify a birds age from the ground while it was feeding. If arboreal camera traps were a possibility in future, a study could be conducted looking into how successfully juvenile *Ara glaucogularis* remove the mesocarp from the *Attalea phalerata* nut, and whether it differed to how successful adult birds were in comparison at removing the mesocarp when feeding.

It is plausible that there were more juvenile birds this year than last year, as the average group size was larger for both species, 6 for *Ara glaucogularis* and 4 for *Ara ararauna* compared to 2 for both species in 2014 (Field, 2014). As the clutch size for both species is thought to be two-to-three eggs per nest this is a possible explanation (Webpage 5; Webpage 6). If this is the case, this would explain why this particular feeding behaviour hasn't been noted before, and would be a positive step for the Barba Azul reserve as it may mean numbers of *Ara glaucogularis* are increasing.

It was found that both Macaw species are significantly more likely to be found feeding in a group comprised of their own species than a mixed flock (Table 5). This is in keeping with the results from figure 19, showing that there is significantly more inter-specific aggression than intra-specific aggression displayed[17]. This indicates that there is a level of competition surrounding the food resource.

No serious aggressive interactions were recorded, in most cases the submissive Macaw would simply move to a different area of the bushel and pick another *Attalea phalerata* nut. Possibly because of when the research was carried out, there were no newly hatched chicks as the breeding season for these species is from November to March (webpage 5). Intra-specific and inter-specific competition in other bird

[17] Though mixed feeding groups were occasionally observed in this research.

species impacts most dramatically on chick mortality (Furness and Birkhead, 1984). Perhaps during the breeding season there is more intense competition for the *Attalea phalerata*. It was noted that *Ara ararauna* dominated the smaller *Ara glaucogularis* the majority of the time when these aggressive interactions were recorded, infrequent though they were[18]. It could also be that if food was to become more scarce, competition with the larger, more vocal *Ara ararauna* could further *Ara glaucogularis'* decline. This is something some previous papers have already posed as an explanation for the low numbers recorded today (Hesse, 2000). More in-depth study. conducted over a longer period of time, would be necessary to verify this, as the low numbers of *Ara glaucogularis* present in the wild mean that specific behaviours, such as aggressive inter-specific interactions, are not frequently witnessed.

[18] Personal observation.

Future studies:

There is still a lot unknown about the nesting and breeding behaviour of these birds, or leading causes of chick mortality and survival rate. Knowing which factors, whether they be predation or habitat loss, are causing the ongoing decrease in numbers seen today is key to reducing this decline. However, this cannot be undertaken by Armonia until they are able to purchase the land the Macaws are thought to breed in (Boorsma,. 2016.). Future research could be undertaken to identify the age *Ara glaucogularis* become independent in the wild, and how long it takes for an *Ara glaucogularis* to master the ability to remove the mesocarp successfully from the nut.

Another possible area of research could be study the *Alouatta Caraya* population. While *Alouatta Caraya* were caught on the camera traps, the resolution was too poor to study them fully, and very little statistical analysis could be carried out from the data. A study undertaken with arboreal camera traps may yield better results and add another dynamic to the interspecific competition surrounding the resource availability in the reserve.

Other potential areas of future research could establish whether *Ara glaucogularis* effectively supplement their diet with other fruits when they are either too young to effectively remove the mesocarp or, if *Attalea phalerata* availability is scarce (as in the east of the reserve) where the land is more degraded by cattle ranching and has less well established *Attalea phalerata* stands (Macdonald,. 2012). The results of this could have implications for how well this species will be able to cope in the future as urbanisation levels increase across the Benis.

Conclusion

Both species of Macaw behaved very similarly. This is not surprising as they share a common ancestor less than 33MYA (family: Psittacidae) (Wright et al., 2008). Comparison studies between these two macaw species are useful for conservation of *Ara glaucogularis.* As *Ara ararauna* have similar requirements to the critically endangered *Ara glaucogularis,* meaning factors that negatively affect one of these species, such as the illegal pet trade and habitat loss, will more than likely affect the other species (Fahrig, L., 2003). To effectively protect *Ara glaucogularis* in the wild it is important to gain as much information about the sympatric *Ara ararauna* simultaneously.

The results in this project highlight the interspecific competition on the reserve, causing hypothesis 4, that there is significantly more interspecific competition than intraspecific competition between Macaw species when feeding, to be accepted. This can be deemed likely due to how similar these two Macaw species niches are (webpage 6). Multiple parallels from the time of day active, to average group size when carrying out the same activity were matching for both species[16.]. For both species average group size was significantly larger when feeding than when not feeding leasing to the acceptance of Hypothesis 2, that group size differs for *Ara glaucogularis* and *Ara ararauna* depending on activity. Average group size for both species had increased from 2014 (Field,. 2014) (figure.15, figure.16) which could mean a successful breeding season in the previous year. However, the results recorded within the reserve cannot be extrapolated to tell how the rest of the *Ara glaucogularis* population across the Benis has fared this year. Again, more research on the age of the Macaws within the reserve would need to be carried out to prove this.

This project proved that the two macaw species employ different techniques to remove the mesocarp from the *Attalea phalerata* nut, with much of the evidence importantly caught on camera. This leads us to reject Hypothesis 3 that Macaws do not leave different markings upon the *Attalea phalerata* nut when feeding. With the second type of marking by *Ara glaucogularis* (figure 5) now identified, this should lead to greater accuracy in *Ara glaucogularis* feeding site identification in future.

The best way of attracting *Ara glaucogularis* to the reserve is likely by having a large, viable *Attalea phalerata* population, as these birds use these trees for both foraging and nesting purposes (Yamashita, C. and de Barros, Y.M., 2013). Macaws and other animal species on the reserve were also observed to forage less during the day in the more heavily ranched east than in the north of the reserve[19]. As such, harmonious relations with local farmers need to be maintained if the reserve expects the farmers to respect their wishes and not allow their cattle to graze within the forest islands, which damages the young *Attalea phalerata* (Boorsma,. 2016). Though in this study Hypothesis 1, that canopy cover affects the type of vertebrate species found feeding in the area, is rejected. If cattle ranching is more tightly regulated and the forest islands are allowed to regenerate, there is the potential for a more diverse canopy layer to develop within these forest islands. This may open up a wider range of niches and lead to a diversification of areas and canopy types which could lead to a greater separation of foraging areas on the reserve utilised by *Ara glaucogularis* and *Ara ararauna* and all other vertebrate species found within Barba Azul (Larrea-Alcázar et al., 2011).

[19] Personal Observation.

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Appendix

Camera trap

After the vegetation survey was done, preferably the morning after as a ripe bushel was consumed, sometimes within 2 days, a Bushnell camera trap was taken to one of the marked fruiting trees. This was placed either underneath the tree on a tripod facing the bushel or, if there was access to a ladder, a camera trap was put up on a tree opposite the one in question facing the bushel. The mode was set to low sensitivity to try and reduce the amount it was set off by canopy movement. Night vision mode was also set as howlers are thought to be active after dark. It was then left for 3 days and checked upon periodically till the memory card was full or the batteries ran out. The camera traps were mainly set up to capture mammal species such as the Black Howler monkeys, which were thought to be mainly active in hours outside of when it was feasible to be in the forest islands.

Raw data

The raw footage from camera traps and hand held video camera can be found on the CD handed in with the field note book.

Excel Sheets with how the raw data was sorted through and used for statistical analysis can be found on a USB memory pen also handed in with the field hand book.

Coordinates of feeding sites and fruiting trees can be found written out in the field hand book.

Example excel table:

no.	Agg	Spp
1	1	A
2	1	A
3	1	A
4	1	A
5	1	A
6	1	A
7	0	A
8	0	A
9	0	A
10	0	A

11	0	A
12	0	A
13	0	A
14	0	A
15	0	A
16	0	A
17	0	A
18	0	A
19	1	B
20	1	B
21	1	B
22	0	B
23	0	B
24	0	B
25	1	AB
26	1	AB
27	1	AB
28	1	AB
29	1	AB
30	1	AB
31	1	AB
32	1	AB
33	1	AB
34	1	AB
35	1	AB
36	0	AB
37	0	AB
38	0	AB
39	0	AB

Figure 20 showing how statistical analyisis was set out on excel for statistical analysis of qualitative data.

Abbreviations (As found in field hand book)

Black Howler Monkey: (HOW)

Blue-Throated Macaw: (BTM)

Blue and Yellow Macaw: (BY)

Peccary: PEC

Oropendola: ORO