Foraging Ecology and Population Size of the Critically Endangered Blue-throated Macaw (*Ara glaucogularis*) and the Sympatric Blue and Yellow Macaw (*Ara ararauna*) on the Barba Azul Reserve, Bolivia

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Abstract

The Bolivian endemic Blue-throated Macaw (*Ara glaucogularis*) is a critically endangered species with less than 200 birds left in the wild (Strem, 2008; Yamashita and Machado de Barros, 1997). This study focused on the foraging ecology and obtaining a population size estimation of this species, and the Blue and Yellow Macaw (*Ara ararauna*), on the Barba Azul Reserve. Surveys on the behavioural ecology of these species included spending time in the forest islands observing birds from the ground and making notes on their behaviours, both in general and in relation to foraging. Some temporal difference in foraging behaviour was seen and explained by the number of macaws in the forest island at different times. Results indicated that the Blue-throated Macaw consumes the fruits of the *Attalea phalerata* palm in a different way from the Blue and Yellow Macaw leading to different characteristic marks in the fruits mesocarp, allowing identification of the macaw which consumed it. These marks were unlikely to be caused by preference in nut size therefore differences in beak morphology is a plausible explanation. By looking at these characteristic markings and behavioural observations it was concluded that both species were foraging in the same areas. The population estimation was conducted using 35 point counts, with stations located around the three main forest islands. A minimum of 52 Blue-throated Macaws, representing more than 25% of the current wild population, and 398 Blue and Yellow Macaws were recorded. The number of Blue-throated Macaws had dramatically decreased from the year previously whereas the number of Blue and Yellow Macaws had increased. Individual forest island utilisation showed that both species utilise BA island to the greatest extent, most likely due to it having a high abundance of *Attalea phalerata* palms and a low level of disturbance from humans and cattle.

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Firstly I would like to thank Dr Ross MacLeod for giving me the opportunity to travel to such a wonderful country to carry out my study. Thank you for giving direction throughout the planning, data recording the long write up stages of this report.

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Contents:

1. Introduction

The Bolivian endemic species *Ara glaucogularis*, common name Blue-throated Macaw (Family Psittacidae), is one of the most endangered macaw species in the world (Hesse, 2000). The global population of the species is currently estimated at less than 200 (Strem, 2008; Yamashita and Machados de Barros, 1997). They inhabit the seasonally flooded savannahs of the Beni Department in the lowlands of north-western Bolivia, an area which is almost entirely unprotected. There are two subpopulations, the larger of which is north of the town of Trinidad consisting of 160 birds, the smaller to its south east with only 25 (Strem, 2008). These two subpopulations are highly fragmented due to cattle ranching, illegal trafficking and annual burning practices, all threats to the survival of the species (Duffield and Hesse, 1997; Hesse 2000). The Barba Azul Nature Reserve, run by the Bolivian Birdlife International partner Association Armonia, lies within the range of the larger subpopulation and is where this study was conducted. This reserve is currently the only protected area for the Blue-throated Macaw.

Little is currently known about the ecology of the Blue-throated Macaw. Previous studies including those by Hesse (2000) and Yamashita and Machado de Barros (1997) have provided us with background information on the ecology of in this species but more detailed research into its reproduction and behaviour is desperately needed in order effectively protect this species in the wild. It is intended that the data collected in this report will help assist conservation organizations such as Association Armonia protect the Blue-throated Macaw and its habitat in future years.

In addition information was collected on the Blue and Yellow Macaw (*Ara ararauna*), another large macaw species thought to have similar ecological requirements to the Blue-throated Macaw (Parr and Juniper, 2010). Previous University of Glasgow Expeditions found that this species is abundant on the Barba Azul Reserve utilising similar resources to that of the Blue-throated Macaw. Collecting data on this species in conjunction with the Blue-throated Macaw allowed us to determine if the behaviour of the Blue-throated Macaw was similar to that of another large sympatric macaw, and if any particular aspect of the Barba Azul Reserve was limiting the number of Blue-throated Macaws residing there.

1.1. Biodiversity in Bolivia

Bolivia (Figure 1.1) is home to a vast array of different habitat types including neotropical rainforest regions, the Andean dry valleys and savannahs. This variety of habitats makes Bolivia one of the most ecologically diverse countries on the planet. According to Ibisch (2005) Bolivia is home to 45% of all South American bird species as well as many mammals, reptiles and amphibians highlighting the incredible species richness that can be found in one country. Until relatively recently little systematic scientific research had been done in the country due to a lack of funding and infrastructure but in the last twenty years conservation and scientific research in this country has been slowly increasing (Langstroth, *in Prep*).

Figure 1.1: Map of South America. Bolivia (shown in the red circle) is a landlocked country situated south-east of Peru and west of Brazil. (Map adapted from World Atlas US, 2010).

1.2. The Beni Savannah Ecosystem

In the north of the Beni department lies the Beni savannah, an assortment of different ecosystems covering an area of around 160,000km^2 with elevations of between 100 and 250m (Mayle *et al*, 2007). The main constituent of the Beni savannah is the Llanos (tropical grassland) ecosystem (126,000km^2) comprised of seasonally flooded savannah plains (Figures 1.2 and 1.3) with an archipelago of forests islands and gallery forests (Mayle *et al*, 2007, Langstroth, *in prep*). The flora of this ecosystem is described by Langstroth (*in prep*) as being 'globally unique' as it includes species from different niches such as Neotropical, Amazonian and cerrado specialist species. Currently there is believed to be more than 5000 plant species found in the Beni savannah as well as 509 bird and 146 mammal species (Beck and Moraes, 1997). The savannah habitat is extremely diverse due to variation between sites in several key characteristics including soil properties, topography and climate hydrological cycles (Langstroth, *in prep*).

Figure 1.2: Shows the Llanos de Moxos (the savannah plains of the Beni) in the dry season. (Photograph by Emily MacDonald)

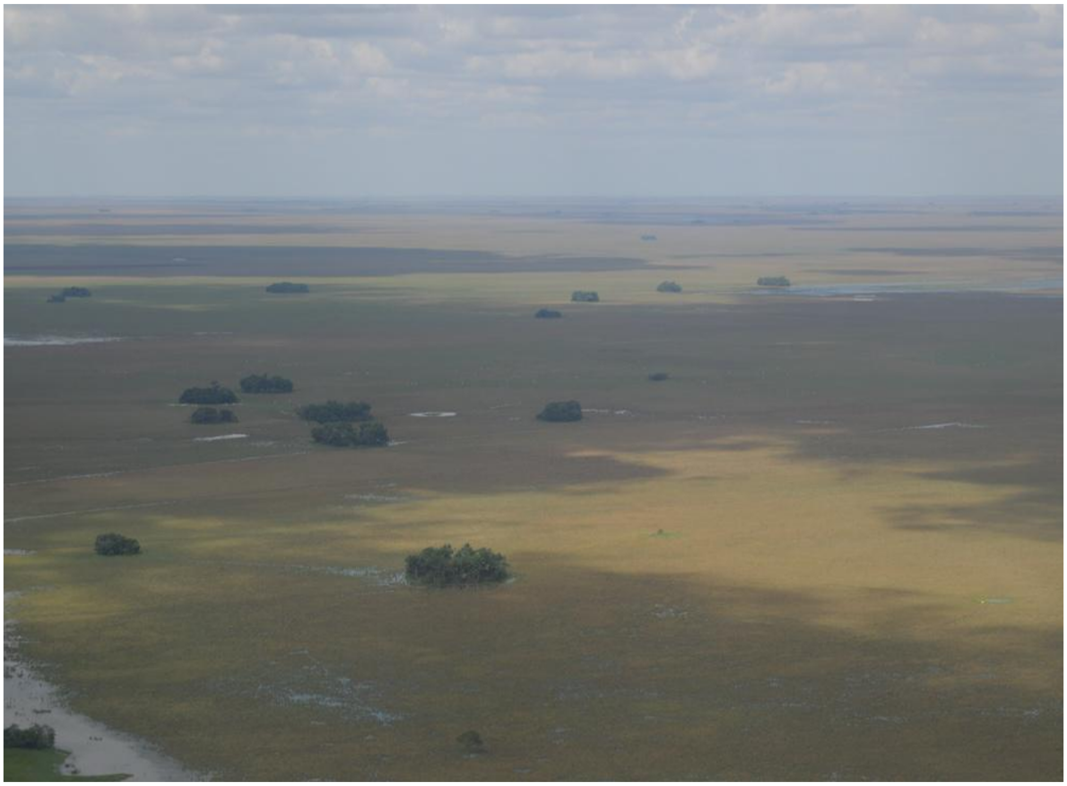

Figure 1.3: Shows the Llanos de Moxos (the savannah plains of the Beni) in the wet season. The flooded areas are clearly visible as well as the raised forest islands. (Photograph from Association Armonia)

Seasonal flooding in the llanos hinders tree growth creating a sub-climaxed habitat of open pampas with a few scattered shrubs and bushes (Langstroth, *in prep*). Interspaced forest islands are formed on raised mounds of earth which are unaffected by seasonal flooding, providing unsaturated soils colonized by woody plants (Langstroth, *in prep*). These forest islands are exploited by many animals and birds including Blue-throated and Blue and Yellow Macaws for foraging, roosting and nest sites. *Attalea Phalerata* (more commonly known in Bolivia as the motacu palm tree) is the dominant palm of the forest islands, a key foodstuff of the Blue-throated Macaw, and arguably a keystone species for many other vertebrates (Langstroth, *in prep*).

1.3. *Ara glaucogularis*

The Blue-throated Macaw is known locally in Bolivia by its colloquial name 'barba azul', meaning 'blue beard' in Spanish, due to it having a patch of blue feathers under its neck resembling a beard. According to a studies by Strem (2008) and Yamashita and Machos de Barros (1997), there are only around 200 wild Blue-throated Macaws left in Bolivia and there are no current studies to suggest that the population trend is increasing. They inhabit the Llanos de Moxos area of the Beni department (Figure 1.4), most of which consists of privately run cattle ranches. They utilise the forest islands and gallery forests of the savannah due to their close association with *Attalea phalerata* as the majority of their diet is made up of the mesocarp of its fruits, not the actual nut within which is the food of many nut cracker specialist macaws (Yamashita and Barros, 1997). According to Hesse (2000) the fact that the Blue-throated Macaw has such a strong association with *A. phalerata* supports the hypothesis that *A. phalerata* is the only outstanding ecological requirement of this particular macaw species.

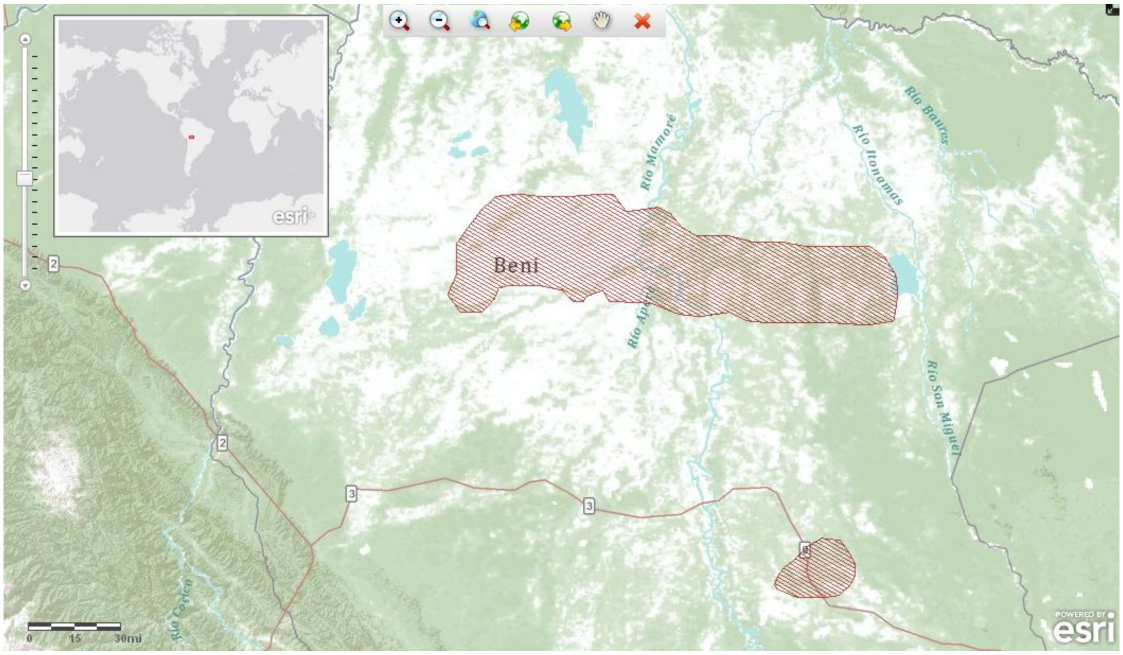

Figure 1.4: Map of the distribution of the Blue-throated Macaw in Bolivia. The red areas define the two different populations- Northern Population believed to be around 160 individuals, the southern population 25 (Strem, 2008). (Map adapted from IUCN red List, 2011b).

The breeding season of the Blue-throated Macaw runs from October/November to March (Duffield and Hesse, 1997; Bird life International Fact sheet, 2011c). They lay 2-3 eggs per clutch which have an incubation period of 26-28 days. Once hatched the young leave the nest after approximately 90-94 days but remain with their parents for months afterwards (Duffield and Hesse, 1997). Not much is really known about the behaviour and ecology of this species in the wild due its rarity and that it was only rediscovered in the wild by scientists around 20 years ago (Jordan and Munn, 1993).

Since 1983 the Blue-throated Macaw has been CITES (Convention on International Trade in Endangered Species of Wild Flora and Fauna) Appendix I listed (Hoyo *et al.* 1997; Hesse, 2000) due to a huge boom in the trade of live birds in the late 1970s and early 1980s. This is the most likely cause of the extremely small size of the wild population today (Jordan and Munn, 1993).

The morphology of this species has many similarities with the large sympatric Blue and Yellow Macaw. In fact until the 1980s it was generally thought that these two species were actually variations of the one species formerly known as *Ara caninde* (Jordan and Munn, 1993). The feathers of the Blue-throated Macaw are typically of a turquoise-blue colour on its back and wings and a bright yellow on its front. It has a broad blue throat patch and narrow blue longitudinal stripes on the side of its face (Figure 1.5) (Parr and Juniper, 2010).

Figure 1.5: Two Blue-throated Macaws, Ara glaucogularis, perched on the fruits of the Attalea phalerata palm (Photograph by Ross MacLeod).

1.4. *Ara ararauna*

In contrast to the Blue-throated Macaw, the Blue and Yellow Macaw (Figure 1.7) *Ara ararauna* (Family Psittacidae) has a very wide geographical distribution stretching across South America (Parr and Juniper, 2010) (Figure 1.6). The Blue and Yellow Macaw can survive in a substantially wider range of habitats than the Blue-throated Macaw, typically inhabiting seasonally flooded and gallery forests, palm swamps and sometimes deciduous forests a considerable distance away from any water source (Parr and Juniper, 2010).

Figure 1.6: Map of the range of the Blue and Yellow Macaw across South America. The red area shows where this species is thought to reside. (Map adapted from IUCN Red List, 2011a).

Figure 1.7: A. ararauna in captivity. Some of its identifying features such as green crown and black throat patch can be seen. (Picture by Gerard Hoffman).

In 2009 the Blue and Yellow Macaw was given the conservation status of ‘least concern’ by the International Union of the Conservation of Nature (IUCN) as there is thought to be around 10,000 mature wild individuals throughout South America (IUCN Red List, 2011a), although there has been no statistical assessment carried out on this species to accurately determine their number (Bird Life International Fact Sheet, 2011a). The species is currently listed on CITES Appendix II, not because it is threatened, but because of its morphological similarity to the Blue-throated Macaw. Since the Blue-throated Macaw is critically endangered any increase in its illegal trafficking could dramatically affect its numbers in the wild therefore it is important to protect Blue and Yellow Macaws as to the untrained eye both species look incredibly similar (Hoyo *et.al*. 1997).

1.5. Current Threats

In the Beni savannah both the Blue-throated and Blue and Yellow Macaw are threatened by the illegal trafficking of live birds, cattle ranching and annual controlled burning practices by ranchers (Duffield and Hesse, 1997; Hesse 2000). The Blue-throated Macaw is particularly vulnerable to the smallest threat or change in its surroundings due to its small fragmented population and low population growth rates (Strem, 2008).

High international trade of the Blue-throated Macaw in the past- in particular the capture of live specimens for the pet trade- is the most likely reason for its low population numbers today (Hesse, 2000; Strem, 2008). In talks with one ex trapper Jordan and Munn (1993) discovered that the individual had taken 1000 Blue and Yellow Macaws and 6-7 Blue-throated Macaws from the wild and sold them to a specialist trader in an unidentified Bolivian City between the years of 1977 and 1983, the year when Bolivia outlawed live bird trade.

Once live bird trade was outlawed in Bolivia black market trade continued which has proved much more difficult to quantify (Hesse, 2000). A recent study by Herrera and Hennessey (2007) examined one illegal trafficking site- the Los Pozos market based in the Bolivian city of Santa Cruz. This revealed large numbers of birds were still being traded in both national and international markets. The study found that between August 2004 and July 2005, 7279 birds from 31 parrot species entered into this market including 105 Blue and Yellow Macaws. In this particular study no Blue-throated Macaws were recorded, perhaps due to the awareness programme set up by Association Armonia or because there are so few of them left in the wild already. From this it was estimated that 22,000 parrots were illegally traded in Bolivia in 2005 (Herrera and Hennessey, 2007). Huge numbers such as these are bound to have a drastic effect on the numbers of Blue and Yellow Macaws, but even more so on the few Blue-throated Macaws left in the wild. Not only are traffickers taking birds illegally from the wild, but also from so called 'protected places'. In 1996 six captive Blue-throated Macaws disappeared from Santa Cruz zoo and were never accounted for again (Herrera and Hennessey, 2007).

In the Beni department all known populations of Blue-throated Macaws reside on privately owned land, the majority of which is used to graze cattle. This has an impact on bird populations through the high level of disturbance to the habitat associated with cattle ranching practices. For example, trees are cleared to increase pasture size which can result in a reduction in potential next sites for the two macaw species under study. Cattle themselves also have a direct destructive effect on the forest island habitat by trampling on the undergrowth and preventing plant regeneration (Duffield and Hesse, 1997).

It has been hypothesised that the effect of cattle ranching will be even greater in the next twenty to thirty years. By preventing regeneration cattle are reducing the number of juvenile plants which reach maturity. This means that when the currently mature trees die there will be fewer trees in the next generation to replace them, potentially putting more strain on Blue-throated and

Blue and Yellow Macaw populations in years to come (Yamashita and Machado de Barros, 1997).

Another threat to bird species in the Llanos de Moxos is the process of annual burning of the savannah grasslands to create richer grazing for cattle in subsequent years. This process has similar effects to those of the grazing itself such as clearance of trees, therefore reducing the number of nest sites, and preventing plant regeneration (Hesse and Duffield, 1997).

1.6. The Barba Azul Nature Reserve

In July 2008 Association Armonia sealed the purchase of the 3558 hectare San Lorenzo ranch in the Llanos de Moxos with generous support from the World Land Trust and the American Bird Conservancy (Hennessey, 2010b). The ranch was renamed the Barba Azul Nature Reserve after the local name for the endemic Blue-throated Macaw it aims to protect. This flagship species has created great interest in the reserve, helping generate revenue for its expansion and application of Association Armonias' conservation aims in years to come. To date this reserve is the only protected area for the Blue-throated Macaw and its habitat (Hennessey 2010b).

In 2010 the reserve was extended with the purchase of the neighbouring Juvena ranch on the southern side of the Rio Omi providing a larger protected area for these charismatic birds. Through the creation and expansion of this reserve other flora species have indirectly benefited. Passerine species such as the vulnerable Black-masked Finch (*Coryphaspiza melanotis*) and

Cock-tailed Tyrant (*Alectrurus tricolor*) (Figure 1.8), have been protected through the blanket protection provided by protecting the Blue-throated Macaw. As have mammals such as the Pampas deer (*Ozotoceros bezoarticus*) and the Giant Anteater (*Myrmecophaga tridactyla*) (Figure 1.9), both have been recorded in high abundance on the reserve even though they are listed by the IUCN as near threatened (Hennessey, 2010b).

Figure 1.8: A Cock-tailed tyrant, Alectrurus tricolor, perched on a blade of grass in the pampas. (Photograph from Association Armonia).

Figure 1.9: Two Giant anteaters (Myrmecophaga tridactyla) recorded by camera traps by the University of Glasgow Bolivia Expedition in 2009.

1.7. Previous Expeditions

To date the University of Glasgow has sent three expeditions to the Barba Azul Nature Reserve (with the fourth already planned for the summer of 2012) to carry out studies of the biodiversity. The students have produced reports on several faunal species/groups of species in order to help conserve them and gain a greater understanding of their ecology. Extensive studies on the reserves mammal's using camera traps and transect studies have revealed the presence of at least 20 mammal species on the reserve including puma (*Puma concolour*) and the maned wolf (*Chrysocyon brachyurus*) (Glasgow University Bolivia Expedition Report, 2010).

Previous studies on the Blue-throated Macaw have mainly focused on estimating the minimum population size utilising the Barba Azul Reserve. The 2010 expedition also looked at the pre-roosting behaviour of these macaws and that of the Blue and Yellow Macaw. Association Armonia have also carried out more observations on the Blue-throated Macaw both in the reserve and throughout the neighbouring ranches including some work on its reproductive ecology, this work has not yet been published.

2. Aims and Objectives

The main goals of this study were 1) to achieve a greater understanding of the foraging ecology of the critically endangered Blue-throated Macaw and the large sympatric Blue and Yellow Macaw, and 2) to estimate the minimum size of the populations of each species utilising the Barba Azul Reserve during the dry season of 2011. In order to achieve these general goals the objectives of this study were as follows:

1. Estimate the minimum number of Blue-throated and Blue and Yellow Macaws utilising the Barba Azul Reserve using regular point count surveys.
2. Identify the different habitat preferences of Blue-throated and Blue and Yellow Macaws within the reserve using point counts around individual forest islands combined with foraging surveys looking at which forest island, and which areas within the forest islands, the birds preferred.
3. Quantify the characteristics of preferred foraging locations with the help of botanical surveys.
4. Investigate how Blue-throated Macaws and Blue and Yellow Macaws consume *Attalea phalerata* palm nuts and attempt to confirm the hypothesis that the two species leave

different characteristic markings in the mesocarp of these fruits as described by Yamashita and Machos de Barros (1997).

5. Use dropped palm nuts and direct observations to investigate whether Blue-throated Macaws and Blue and Yellow Macaws forage together in the same areas.
6. Identify if there are temporal differences in foraging behaviour.

3. Methods

3.1. Study Site: The Barba Azul Nature Reserve, Beni Department, Bolivia

The Study was conducted on the Barba Azul Reserve (Latitude (degrees, minutes N or S) 13 44’ 17’’ S Longitude (degrees, minutes E or W) 066 04’ 33' W) owned by Birdlife International Bolivian partner Association Armonia, and situated in the Beni Department, Bolivia (Figure 3.1) For the purpose of this report the original Barba Azul Reserve (3558ha) and the new Juvena ranch (1160ha) will be referred to as one large reserve by the name of Barba Azul and to these two different areas within it as sections within it. The outline of the entire reserve is shown in Figure 3.2 as well as the outlines of the two separate sections. The two sections are physically divided by a river, the Rio Omi, which floods during the wet season leading to flooding across much of the grasslands.

The two sections have been subject to different human pressures over the last four to five years due to the original Barba Azul section being protected for a longer period of time. For example there were many more cattle grazing on Juvena than in original Barba Azul during this study, as they had not yet been removed by neighbouring ranchers (Mauricio Herrera, personal comment). These cattle are likely to be removed by Association Armonia in this coming year in order to further protect the area.

Both of the reserve sections were included in this study and both comprise a variety of habitat types including seasonally flooded savannah grassland, wooded grassland with interspersed trees known as cerrado and forest islands/gallery forest, which is the habitat that the Blue and Yellow and Blue-throated Macaws utilise the most within this ecosystem (Parr and Juniper, 2010).

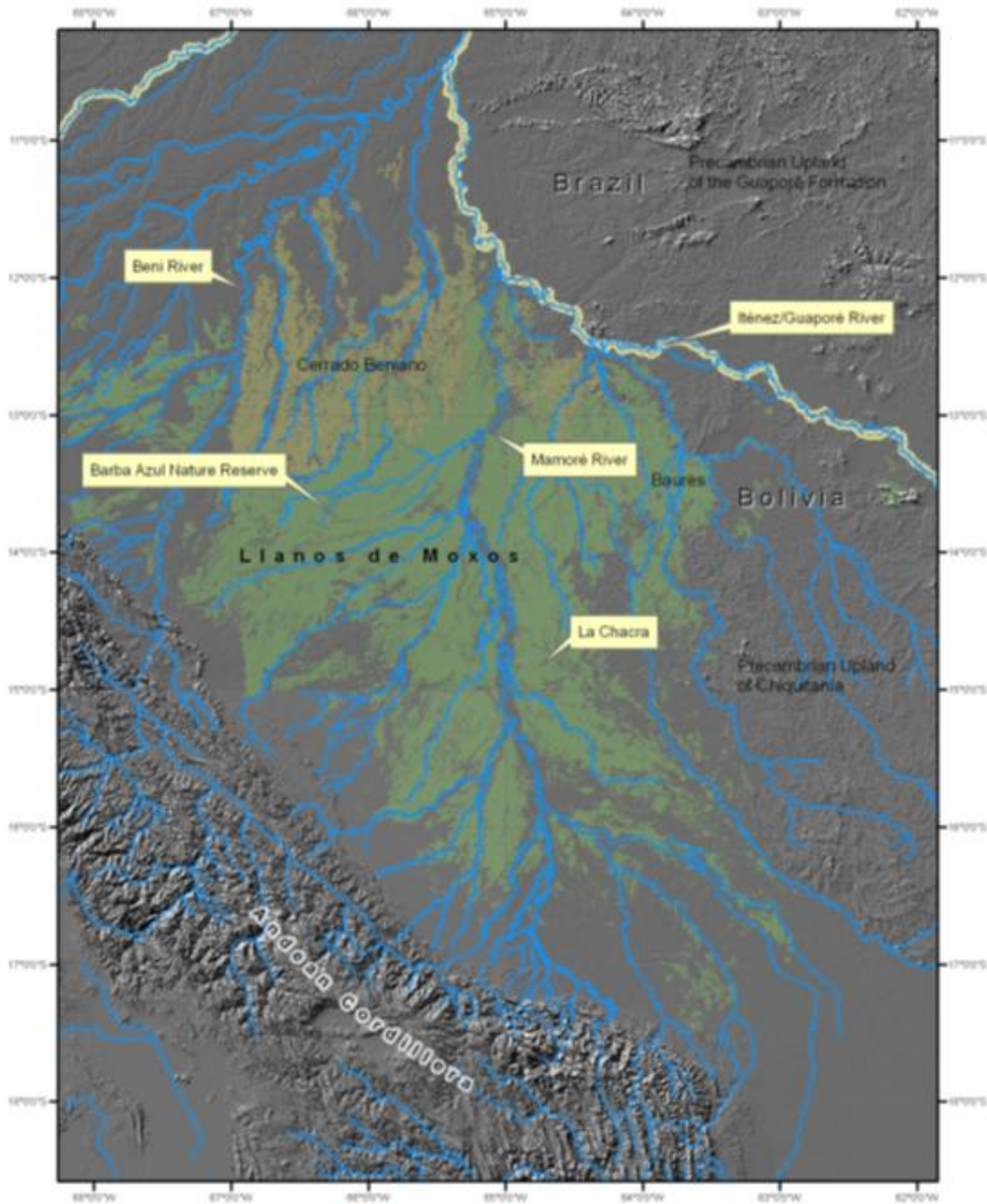

Figure 3.1: The Llanos de Moxos Region, Beni Department, Bolivia. The Llanos de Moxos is shown in green and the Beni Savannah in brown. The Barba Azul Nature Reserve is shown. (From Langstroth, in prep)

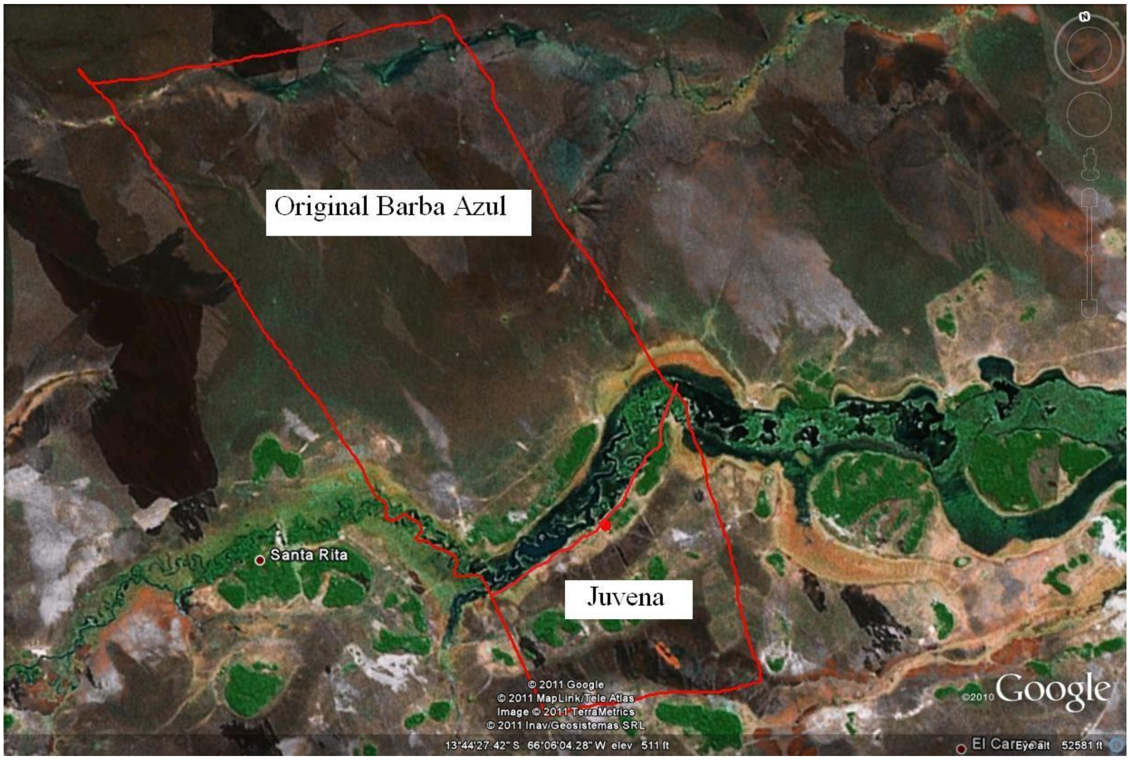

Figure 3.2- Satellite map of the Barba Azul Nature Reserve. The Barba Azul and Juvena sections are highlighted (Adapted from Google Earth maps).

3.2. Group Training and Species Differentiation

The data for the study was collected by the University of Glasgow Bolivia Expedition 2011 which consisted of eight Glasgow students and one Bolivian student. Before any data was collected field workers were trained in the identification of the two macaw species in the field based on their plumage differences and distinctive calls. It was vital that field workers could tell these two large sympatric species apart from each other whilst perching and flying from a substantial distance, sometimes more than 100m away. One main way in which the macaws were identified was by looking at the colour and size of the patch of feathers on their throat. If the patch was blue and extended down the front of the bird then the individual was a Blue-throated Macaw. In Blue and Yellow Macaws this patch is black and much smaller (personal observations; Parr and Juniper, 2010) (Figure 3.3). Another way in which these birds could be identified was by their distinctive calls as the call of the Blue-throated Macaw is higher pitched and less raspy in sound than that of the Blue and Yellow (personal observations; Jordan and Munn, 1993). Each field worker quickly learned their own effective way of telling these two species apart and therefore species identification by all field workers was considered reliable.

Figure 3.3: Plumage differences between the Blue-throated Macaw (left) and the Blue and Yellow Macaw (right). The difference in colour and size of the throat patch is distinctive and easily seen in the field. (Photograph from Association Armonia).

Training was given on how to approach these birds quietly as to not disturb their natural behaviour. Field workers were also introduced to Global Positioning System (GPS) receivers (Garmin), in particular how they can be used to mark waypoints, as well as how to use binoculars and compasses correctly.

This training was provided by myself and two other expedition members who had spent time on the reserve previously. This helped mitigate many of the errors which could have occurred, such as misidentification of species, if sufficient training had not been supplied. As an additional way of ensuring quality and consistency of data I was present during all foraging behaviour data collection sessions, along with one other trained fieldworker. This allowed for any observations which could have resulted in differences in observer judgment to be kept to a minimum.

3.3. Selection of suitable forest islands

The focus of the study was on three forest islands which Blue-throated and Blue and Yellow Macaws are known to utilise during the daylight hours (Mauricio Herrerra and Bennett Hennessey, personal comment). Two of these islands are in the newer Juvena section, and are named Los Maneches (LM) and Fortuleza (FO), whilst the other, named Barba Azul (BA), is situated in the original Barba Azul Reserve. BA island runs along the river in the original Barba Azul section and is on the whole undisturbed by cattle and human activities. It was chosen as it had already been studied by the University of Glasgow Bolivia Expedition in the previous two years giving the potential for this study to be compared with previous work. Islands LM and FO were chosen because they were larger than the others on the Juvena section and, according to the staff at Armonia, were utilised by many Blue and Yellow Macaws. Both these islands are subject to greater disturbance from ranching than BA island as a large number of cattle are still being grazed on this area (personal observations). FO also included a large section of once cultivated mango trees making the island semi artificial. The locations of these islands within the reserve are shown in Figure 3.4.

There are several other much smaller islands (~100m in diameter) in the North Easterly part of the original Barba Azul Reserve, and in the Juvena section, which were not included in the study that the two macaw species may utilise for resources during the daylight hours. Due to time constraints and a limited number of field workers it was not practical to include these in the study. This was not considered to be a significant problem as, according to Association Armonia and previous studies by the University of Glasgow Bolivia Expedition, the numbers of both species which utilise these areas are minimal (Glasgow University Bolivia Expedition Report, 2010).

Figure 3.4- Satellite map showing the locations of the three forest islands under study within the reserve (Adapted from Google Earth maps).

GPS waypoints were taken at intervals around each of the islands to help estimate their area. All three islands were roughly rectangular therefore the basic mathematical formula of Area=Length x Breadth (A=LxB) was used. The area of any large gaps of trees or patches of cerrado within this calculated rectangle was calculated and subtracted from its area. What was left was essentially an estimate of the area of each island.

3.4. Pilot Study

During the initial days on the reserve the expedition carried out a small pilot study (approximately six hours of the foraging behaviour study and one individual island point count) to assess which research methods would be most appropriate for this study. At first line transects were planned for the foraging behaviour study but this proved to be an inefficient data collection method as both macaw species tended to cluster together in particular areas of the forest islands meaning that time was wasted looking for macaws in areas which they did not utilise. For this reason walking searches, which followed no particular transect, were used instead. A pilot point count was also carried out around BA island to allow fieldworkers to consolidate their macaw species identification expertise.

The pilot study gave field workers the opportunity to practice the skills they had been trained in before any data was included in the study therefore reducing potential errors.

3.5. Population Size Methods

3.5.1. Minimum population size estimation: A population estimation study was conducted by using stationary point counts around each of these three islands at the same time. Techniques such as capture-mark-recapture were not considered due to stress on the birds, time constraints, equipment expenses and a lack of experience in these procedures. Assessing all three islands at the same time was designed to produce a minimum estimation of the overall population of both species utilising this area (the majority) of the reserve.

It is important to consider that some macaws may have flown out of the forest islands to roost which were not seen and recorded by a fieldworker due to the size and shape of the islands even though every effort was made to position each recording station so that the maximum range of visibility was achieved. With this in mind the data collected represents the minimum number of

Blue-throated and Blue and Yellow Macaws utilising these forest islands during the daylight hours.

When looking at all 3 islands (the total point count survey) seven stationary points were selected around the perimiter of the islands and were kept constant throughout the study (Figure 3.5). These particular stations were selected because they provided a good field of veiw of a large section of the forest island, and together they covered the vast majority of the islands perimeter ensuring that as few as possible macaws failed to be recorded. During the point counts the observers recorded the following information about the Blue-throated and Blue and Yellow Macaws detected including: number, species and whether they left, arrived or flew over the island of study (the island the observer was located closest/next to). Time and the direction of flight was also noted to minimize the chance of the same bird being counted twice from two separate points, along with the weather on the day of recording so that any effects weather might have on number of birds could be investigated. The study was carried out between 16:30 and 18:30 since the pilot study and previous observations by University of Glasgow Expeditions show that at this time the two macaw species leave these forest islands to roost in other areas inside and out with the reserve (currently no reports of roosting in any of the three study islands (Association Armonia Staff, personal comment)). If, as happened on some occasions, a significant number of birds were still seen to be leaving the island at 18:30 observers stayed for an extra ten minutes at the end of the study to ensure they recorded all birds leaving (the study was not extended later due to safety concerns regarding fieldworkers returning to camp after sunset). The total point count survey was carried out five times, approximately once per week, during the expeditions six week stay on the reserve, giving a total of 35 point counts. These particular point counts are referred to as the ‘three island/total point counts’ throughout the remainder of the text.

Observational Stations	GPS Waypoint
1	S 13°45.821' w066° 06.779'
2	S13° 44.778' w066° 05.852'
3	S13° 45.832' w066° 05.880'
4	S 13° 45.269' w066° 05.484'
5	S13° 46.038' w066° 06.503'
6	S13° 46.672' w066° 06.034'
8	S13° 46.681' w066° 05.746'
9	S 13° 45.681' w066° 05.746'

Table 3.1: GPS waypoints (in degrees decimal minutes) for each of the observational points used during the point count surveys around the perimiter of the three forest islands.

Figure 3.5: Satellite map showing the stationary points used for the total point count survey. The red dots show the location of the stationary points around the three main forest islands. They were numbered 1 to 9 and refer to the GPS waypoints in Table 3.1. Note that points 8 and 9 were not used in the total point counts; they were only used in the individual island counts. (Adapted from Google Earth maps).

Before analyzing the data it was important to avoid any double counting that might have occurred because birds flew over more than one set of field workers. In reality I could not be certain that no birds would be double counted (or not counted at all) so a set of rules were developed to minimize any effects when the results were analyzed. The majority of macaws from both species flew northwards over the reserve to roost out with its boundary, however a number of the two species did leave the reserve in other directions. From this information it was decided that only macaws flying over each station in certain directions, and those recorded leaving the forest islands, would be used to calculate the minimum population estimation. This meant that macaws flying over stationary points in the southern area of the reserve would not be counted again flying over stationary points north of these. For example, of all macaws recorded flying over point 4 only those flying in an east/north-east direction were included in the minimum population estimation as those flying in other directions would be included at other stationary points. The directions of flight of birds recorded flying over each stationary point, which were included in the minimum population estimation, are illustrated in Figure 3.6.

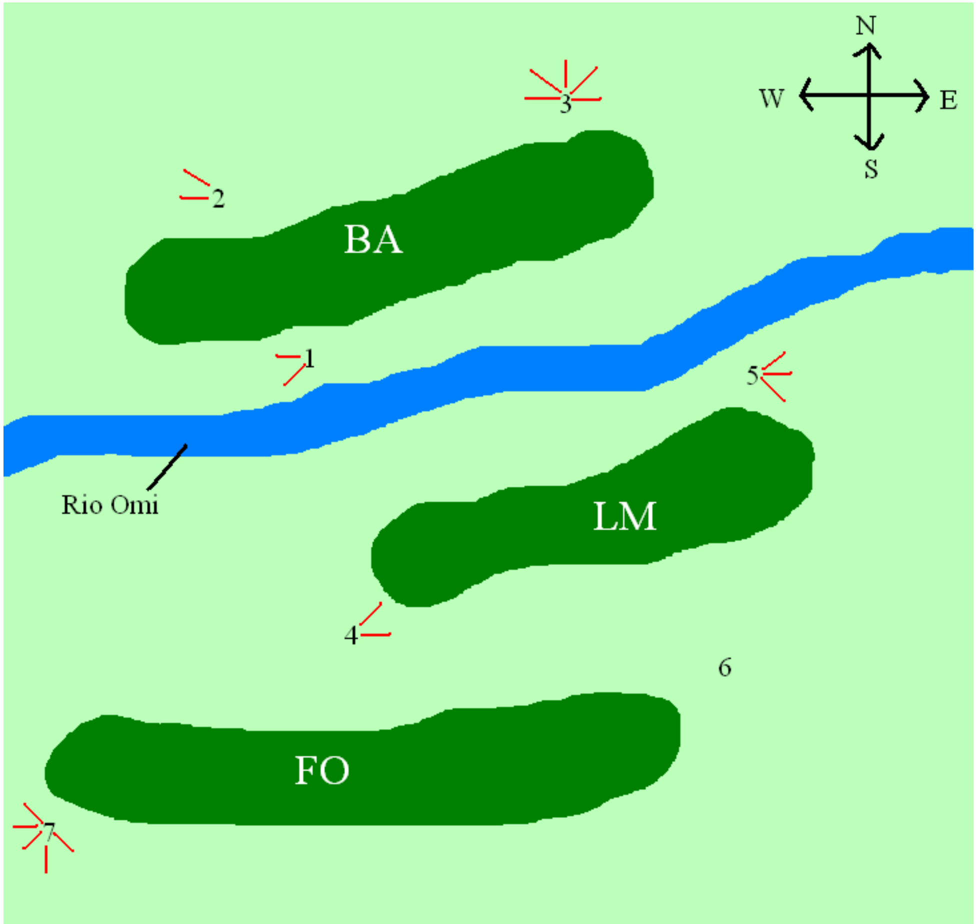

Figure 3.6: The flight directions of macaws flying over which were used in the population size estimation at each stationary point. The red lines coming out of each observational point (numbers) show the direction of flight of those birds which flew over included in the study i.e. of those recorded flying over point 4 only those flying in an east/north-east direction were included in the minimum population estimation as those flying in other directions would be recorded at other stationary points.

3.5.2. Estimating the sizes of populations using the individual forest islands: For the purpose of this study 'utilisation' is defined as the number of individuals flying out of each forest island to roost, in other words the number leaving is the number actively using the islands resources. Looking at each of the forest islands separately gave a deeper understanding of which particular island/ area within the reserve that the two species use and therefore action could then potentially be taken to conserve these sites in years to come.

When looking at the islands individually two extra stationary points (stations 8 and 9) were added in for greater accuracy, one around LM island and one around FO island (Figure 3.5). This allowed for a more in depth comparison between Juvena and Barba Azul foraging populations allowing us to see if there were any particular areas within the reserve being used the most by either species. It also made the results more accurate as it reduced the number of birds which escaped counting. The same data was collected between 16:30 and 18:30 as discussed above at separate times for each island but each study session was only carried out four times over the study period, giving a total of 12 point counts per forest island. These particular point counts are referred to as the 'individual island point counts' in the remainder of the text.

3.6. Foraging Behaviour Methods

Macaw foraging behaviour was assessed in the three selected forest islands with a more in depth study in the BA island as it was quickly realised that the overwhelming majority of Blue-throated Macaws were observed/heard foraging there.

Before any data was recorded a list of defined behaviours to be noted down when observing both macaw species was created (Table 3.2). These behaviours were described to each field worker in detail and were shown to them during the study by myself.

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
Climbing	Individual crawls/hops along a branch or to another branch
Fly off	Individual leaves perch and flies out of field workers range of vision
Foraging	Removing *A. phalerata* palm nuts from husk, flying between trees, chatty calls, consuming mesocarp of nut etc.
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 etc.
Change of position	Change of position on same branch e.g. turns around 180 degrees.

Table 3.2: Behaviours of Blue-throated and Blue and Yellow Macaws recorded by field workers and their brief descriptions.

Initially two mornings (between 7:30-10:30am) were spent in each island searching for macaws and noting down behaviours. In the initial planning stages it was thought that specified transects would be used but this was found to be a difficult way to locate the macaws as they tended to gather in certain areas within each island. A far more effective method was for the field workers (no more than two during any one survey) to walk through the forest island actively looking for macaws but following no particular transect for a period of three hours, listening out for macaw calls and other indicators of their presence. Once a group of macaws was located some general observations were recorded including time, number, tree type (motacu, perennial non-fruiting or perennial fruiting) and any other noteworthy features (grooming, calls, agnostic behaviour, interactions between species etc.). If the macaws were clearly visible then a ten minute individual observation was carried out. Each field worker would watch one bird for ten minutes noting down all its behaviours (Table 3.2). If the individual flew away during the ten minutes the time was noted and the observations were stopped. All field workers used binoculars of at least 8x10 magnification and some observations were taken from a stationary point using a telescope. Whenever any data was recorded a GPS waypoint was taken for mapping out a visual image of where exactly foraging was taking place once the study was complete.

The more in depth study focusing in on BA island consisted of nine observational sessions across 3 time periods: three surveys between 07:30-10:30, three between 11:00-14:00 and three between 15:00-18:00 so that a temporal comparison of foraging behaviour could be made. The same general and individual observations were carried out as described above.

3.7. *Attalea phalerata* palm nut study

Coinciding with the foraging behaviour study an *Attalea phalerata* palm nut study was also conducted. According to Yamashita and Macho de Barros (1997) the Blue-throated and Blue and Yellow Macaw leave different characteristic marks in the sticky orange mesocarp of this nut when they consume it making it possible to differentiate between fruits eaten by these different macaw species. This study aimed to confirm these findings and go further by using these characteristic marks to determine whether Blue-throated and Blue and Yellow Macaws forage together or not. Before data was collected *A.phalerata* nuts which had definitely been eaten by each species (seen to be dropped from the trees by a Blue-throated or Blue and Yellow Macaw) were examined and shown to all fieldworkers. Figure 3.7 shows the species specific marks left in the mesocarp as well as nuts eaten by the smaller Golden collared macaw (*Primolius auricollis*) which also inhabits the area.

Figure 3.7: Characteristic marks on Attalea phalerata palm nuts.The characteristic banding pattern ('spin tracks') caused by the Blue-throated Macaw is seen on the left and the longitudinal markings caused by the Blue and Yellow Macaw in the middle. Primolius auricollis leaves neither of these types of markings and forgaes on smaller palm nuts. Freshness scale 2. (Photograph by Joanne Kingsbury).

Whilst searching for macaws during foraging behaviour studies the observer also examined the ground under *A. phalerata* palms where either species had been observed feeding. Any eaten/

half eaten palm nuts with marks characteristic of either species were counted and recorded. Other *A. phalerata* nuts which were found randomly under motacu trees without foraging birds above were also recorded. The freshness of the nuts was documented in categories 1, 2 and 3 as described below. It is important to note that these categories were somewhat subjective and were affected by environmental conditions such as temperature, rainfall, insect activity and sunlight exposure etc.:

1- Fresh nut, yellowy-orange coloured flesh, sticky, moist and malleable to touch. Thought to have been eaten in last few hours before any decomposition (by ants etc.) (Figure 3.8).
2- Yellowy-orange flesh visible but slightly darker, not sticky or malleable. Dried out and hard to touch. Markings still very clear and set into the flesh. Thought to be around 1-3 (a few) days old (Figure 3.7).
3- Flesh is white/grey in colour, hard, dried out. Markings are visible and set into the flesh (only if ants etc. have not destroyed markings). Thought to be more than 3 days old (Figure 3.9)

These categories allowed us to work out roughly how long ago macaws were foraging under the tree therefore if both species were foraging at roughly the same time. The older the palm nuts were the less accurate the timing was as they were more likely to be affected by environmental conditions and decomposition makes characteristic marks less visible. The length and breadth (to the nearest mm) of a sample of nuts eaten by both species was also taken which allowed for any difference in the preference of nut size in each species to be examined.

Figure 3.8: Attalea phalerata nut of freshness rating 1 consumed by a Blue-throated Macaw. Found on the forest floor of BA island (Photograph by Ross MacLeod).

Figure 3.9: Shows A. phalerata palm nuts of freshness level 3. The two nuts on the left where consumed by a Blue-throated Macaw and the two on the right consumed by Blue and Yellow Macaw. The characteristic markings of each can be clearly seen (Photograph by Ross MacLeod).

3.8. Botanical Survey

A small botanical study was carried out with the help of experienced local botanist, Aquilino Molina Olivera, in all three inlands to get a general idea of the tree composition in each area to be used in conjunction with the individual island point counts. In particular the distribution and features of the *A. phalerata* palm were examined. From this any relationship between tree height, DBH (diameter at breast height), the number of fruiting trees or abundance and the number of foraging macaws could potentially be calculated.

Five 10m by 30m rectangular transects were marked out in different areas of each forest island. Some were placed at random and others in areas where groups of macaws were seen foraging. Within these transects the species, height (taken from ground to the base of the crown using a clinometer) DBH and whether the tree was fruiting or non-fruiting was recorded.

3.9. The Effect of Weather

The weather was recorded at the start of each recording session (point count study and foraging behaviour study) by selection the weather condition from a choice of categories: sunny, rain, cold/rain, cold/wind or overcast/cold. Twice during the six week study period the weather conditions became unfavourable for the macaws (cold/rain/wind) but due to time constraints point count studies were still continued. GLM (general linear model) analysis was used to examine the individual point count data to determine if weather had an effect on the number of Blue and Yellow and Blue-throated Macaws utilising the forest islands. The individual island counts were used as the most weather variation was recorded throughout this study.

3.10. Analysis of Results

Some of the results were analysed statistically through the use of general linear models (GLMs) to identify any relationship between response and explanatory variables. For example, a GLM was used when looking at individual forest island utilisation to uncover any relationship between the number of Blue-throated and Blue and Yellow Macaws leaving around each of the stationary points. A GLM was also used to find out if weather had an effect on the number of macaws recorded as well as several other relationships throughout the study.

Results were illustrated graphically in the form of histograms with standard errors included, allowing patterns in results to be visualised clearly. A satellite map was adapted to show where exactly within BA island both species of macaws were observed foraging.

The majority of the foraging behaviour study is reported in the written form. It includes several descriptions of macaw behaviour including the way in which Blue-throated and Blue and Yellow Macaws consume the mesocarp of *A. phalerata* palm nuts as well as how they react towards the other species.

4. Results

4.1. Forest Island Areas

The estimated area for the three islands under study is shown in table 4.1.

Forest Island	Area (m^2)
BA	1368000
LM	332979
FO	1178000

Table 4.1: The estimated area for each forest island- BA, LM and FO.

4.2. Population Size Results

4.2.1. Minimum Population Size Estimation: From the total point count data the estimated population of the Blue-throated Macaw utilising the reserve was 52 birds and the minimum population of the Blue and Yellow Macaw was 398 birds (Table 4.2 and Figure 4.1). The total number of Blue-throated Macaws on the reserve varied from 9 to 52 individuals and Blue and Yellow Macaws from 199 to 398 individuals on any one study day. As expected the frequency of Blue-throated Macaws was far lower than that of Blue and Yellow Macaws, as approximately ten times more Blue and Yellow Macaws used the Barba Azul Reserve than Blue-throated Macaws. The largest recorded flock of Blue-throated Macaws was 21 individuals which flew over point 3 in a northerly direction, the largest flock of Blue and Yellow Macaws consisted of 47 birds which flew over in the same direction.

Date	Number of Blue-throated Macaws Recorded	Number of Blue and Yellow Macaws Recorded
26/07/11	52	364
02/08/11	26	374
09/08/11	9	398
16/08/11	35	282
24/08/11	32	199
Average Number Across the Study	30.8	323.4

Table 4.2: The minimum number of Blue and Yellow Macaws and Blue-throated Macaws recorded on the reserve during each total point count.

Figure 4.1 suggests no obvious relationship between the number of Blue-throated Macaws and time as the number of individuals' increases and decreases throughout the study period. On the other hand there is a pattern in the number of Blue and Yellow Macaws. Their number remains relatively constant over the first three study sessions (26/7/11, 2/8/11, 9/8/11) and then decreases by approximately 100 individuals in both the fourth and fifth sessions respectively (16/8/11, 24/8/11).

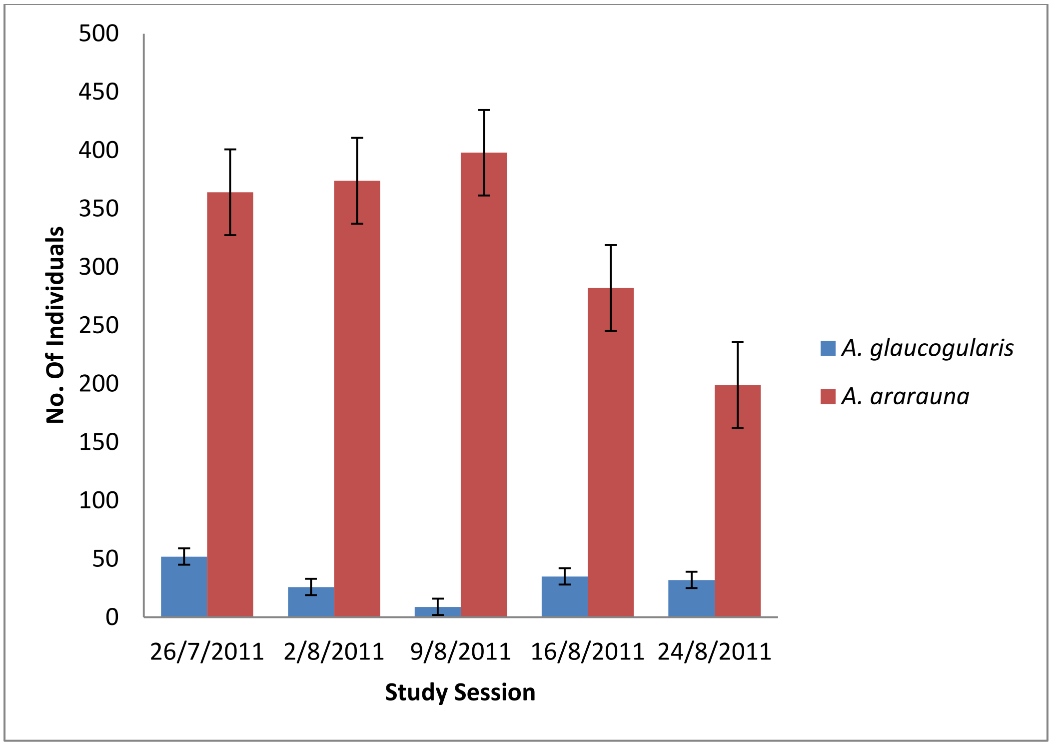

Figure 4.1: Number of A. ararauna and A. glaucogularis using the reserve for each total (three island) point count study session (error bars show the standard error of the mean value).

4.2.2. Estimating the sizes of populations using the forest islands: There was a large difference between the number of Blue-throated and Blue and Yellow Macaws utilising each of the three forest islands (see Table 4.3 and Figure 4.2). No Blue-throated Macaws were recorded utilising islands LM and FO over the entire study, however a significant number of Blue and Yellow Macaws were recorded utilising these islands (up to 45 birds utilising LM island and 127 utilising FO island). Both species were recorded using the BA forest island to the greatest extent (up to 30 Blue-throated Macaws and up to 133 Blue and Yellow Macaws).

Forest Island	Date	No. of Blue-throated Macaws	No. of Blue and Yellow Macaws
BA	07/8/11	0	56
	08/8/11	2	133
	12/8/11	11	41
	22/8/11	30	30
LM	27/7/11	0	3
	04/8/11	0	45
	11/8/11	0	19
	17/8/11	0	2
FO	28/7/11	0	127
	03/8/11	0	13
	10/8/11	0	22
	18/8/11	0	8

Table 4.3: Number of Blue-throated and Blue and Yellow Macaws utilising each of the forest islands across all individual forest island study sessions.

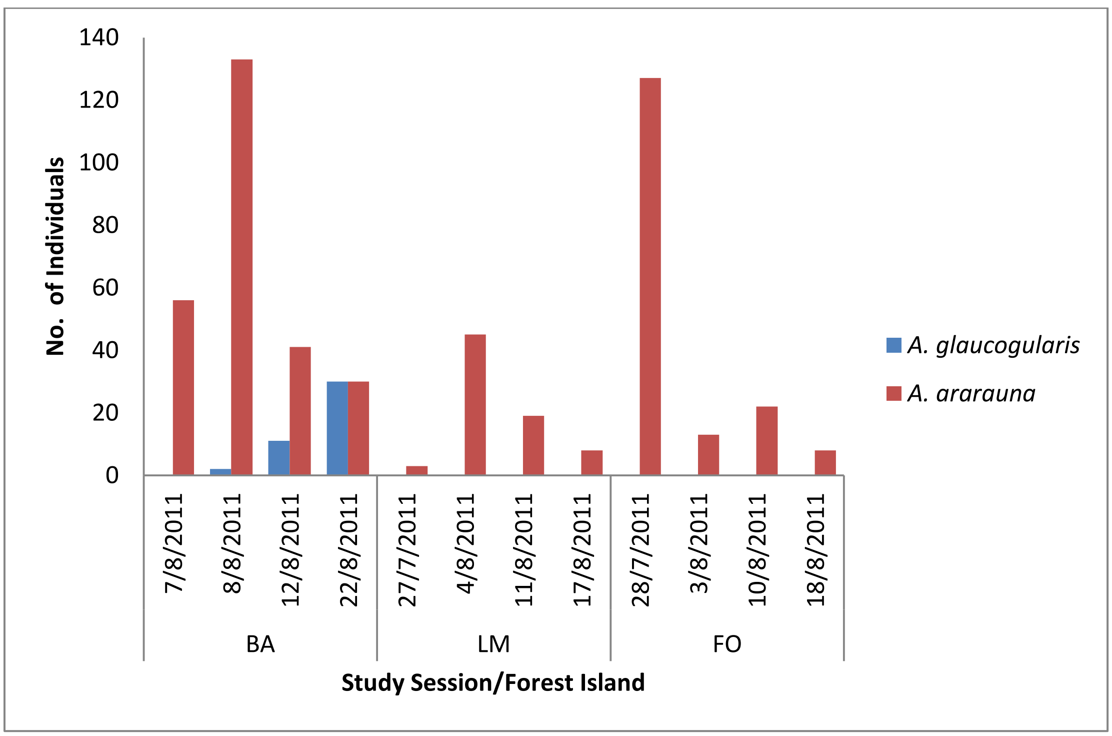

Figure 4.2: Numbers of A. glaucogularis and A. ararauna recorded across all three islands during individual island point counts.

There was a visible difference in the number of both macaw species recorded leaving around the different stationary points (Figure 4.3). No Blue-throated Macaws were recorded leaving islands FO and LM but they were recorded leaving from stations 1 (n=13) and 3 (n=28) around BA island. The vast majority if Blue and Yellow Macaws (n=201) (and to some extent Blue-throated Macaws) were recorded leaving around point 3 of BA island, compared to other points around that island, and to both the other forest islands. GLM analysis (Tables 4.4 and 4.5) showed that there was a significant difference in the number of Blue and Yellow Macaws recorded leaving from each of the stationary points around BA island (P=0.015, R-sq=60.49%) but showed no significant difference when Blue-throated Macaws were analysed (P=0.252, R-sq= 26.38%).

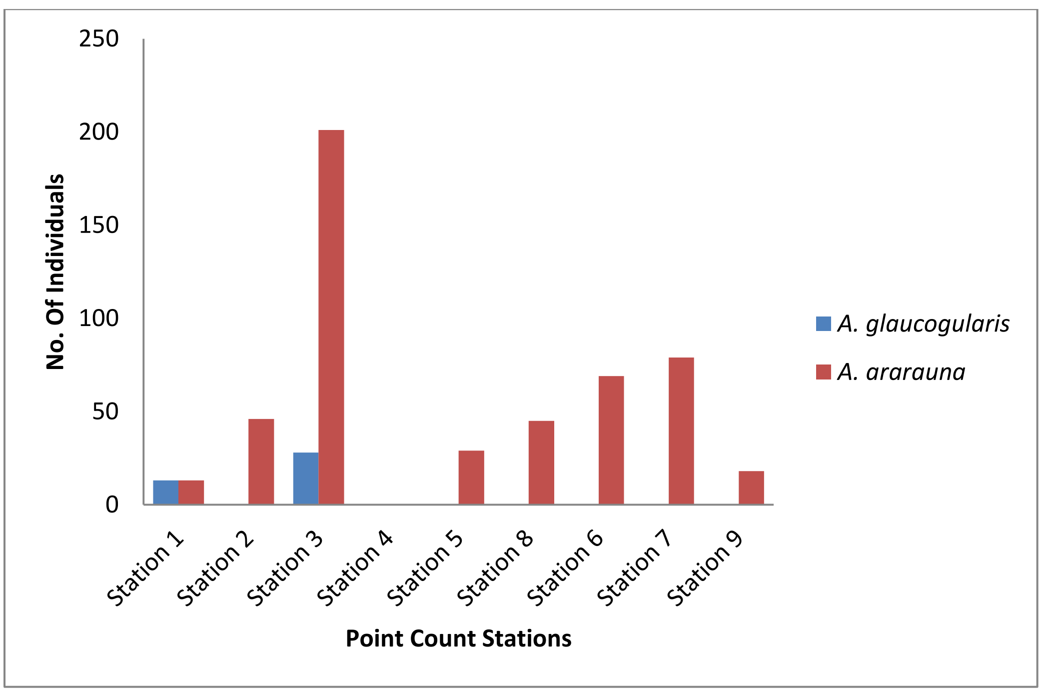

Figure 4.3: The total number of A. glaucogularis and A. ararauna recorded leaving around each point count station across all individual island point counts. There is a much higher number of both species leaving from around stationary point 3 (n=201 for A. ararauna and n=28 for A. glaucogularis) compared to all other stationary points across all three islands.

Source of variation	Sum of Squares	df	F	P	Parameter estimate	Standard Error
Stationary Point	5038.2	2	6.89	0.015	Point 1=-18.417	7.806
					Point 2=-10.167	7.806
Error	3290.5	9				
Total	8328.7	11				

Table 4.4: Summary of GLM results looking at the number of Blue and Yellow Macaws recorded leaving from each stationary point around BA island. A significant result indicates that there is a difference (pattern) in the number of individuals leaving from different parts of the forest island.

Source of variation	Sum of Squares	df	F	P	Parameter estimate	Standard Error
Stationary Point	113.2	2	1.6	0.252	Point 1=-0.333	2.418
					Point 2=-3.583	2.418
Error	315.7	9				
Total	428.9	11				

Table 4.5: Summary of GLM results looking at the number of Blue-throated Macaws recorded leaving from each stationary point around BA island. The non-significant result indicates that there is not a difference (pattern) in the number of individuals leaving from different parts of the forest island.

4.3. Foraging Behaviour Results

A total of 20 Blue and Yellow Macaw and 8 Blue-throated Macaw foraging observations were made across the general study in all three islands, and in the detailed study in BA island. These observations involved the two macaw species taking *A. phalerata* palm nuts from a tree and flying off to stable perch to consume them. The largest flock of foraging Blue and Yellow Macaws recorded was approximately 30 and the largest flock of Blue-throated Macaws was approximately 10 (these figures are approximations as it was difficult to count macaws due to dense foliage).

It was quickly noticed that Blue-throated and Blue and Yellow Macaws ate *A. phalerata* palm nuts in different ways. The Blue and Yellow Macaw ate by holding the nut at its base with one foot so that the nut was orientated vertically (upwards). It then put its whole beak over the top of the nut and scraped upwards (Figure 4.4). The Blue-throated Macaw held the nut at its base with one foot in a similar way to the Blue and Yellow Macaw but it rotated its foot so that the nut was orientated horizontally. It then used its beak to scrape the flesh from the nut horizontally whilst spinning the nut around with its foot (Figure 4.4). The Blue-throated Macaw was observed eating *A. phalerata* nuts once whereas the Blue and Yellow Macaw was observed six times. This appears to be how the species specific marks on the nuts are formed as described by Yamashita and Macho de Barros (1997). The marks of the Blue and Yellow Macaw go along the length of the nut, are reasonably smooth and are not engraved too deeply into the mesocarp. The marks created by the Blue-throated Macaw are deep and spin around the nut horizontally along its length (Figures 3.7, 3.8 and 3.9).

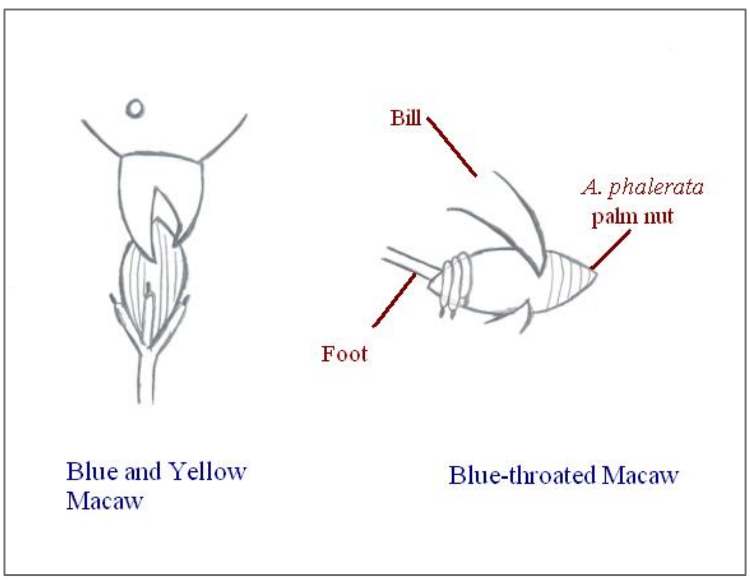

Figure 4.4: Consumption of A. phalerata palm nuts by Blue and Yellow Macaws and Blue-throated Macaws.

The number of times that both macaw species was recorded foraging was examined for temporal variation (Figure 4.5). The majority of foraging behaviour was witnessed in the afternoon study periods between 11:00 and 2:00pm (for the Blue-throated Macaw n=4 and for the Blue and Yellow Macaw n=7). One observation of both species was recorded in the evening sessions, but more Blue and Yellow Macaws were observed foraging throughout the morning studies (n=4) compared to the Blue-throated Macaw (n=2).

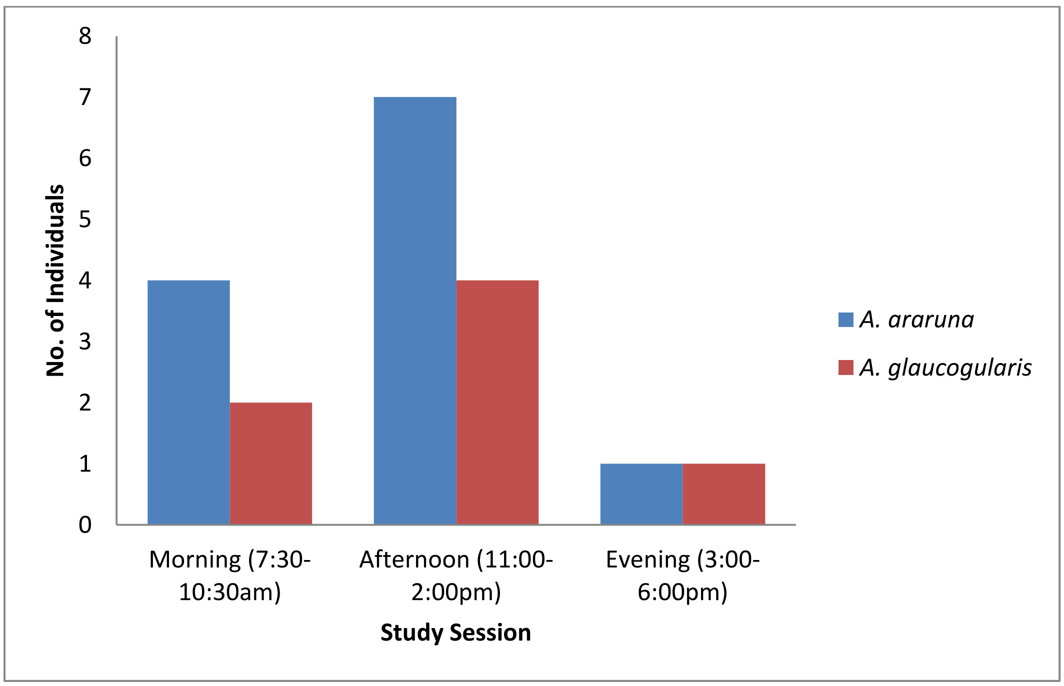

Figure 4.5: The number of times A. glaucogularis and A. ararauna were recorded foraging across different set time periods in BA island. (n=19)

Figure 4.6 shows a visual representation of where the two macaw species were foraging within BA island. A total of 19 foraging observations were made in BA island, however GPS waypoints were only recorded for 13 of these due to an error by a field worker. Ten observations were of flocks consisting of only one species (Blue and Yellow Macaw and Blue-throated Macaw only observations) while the three others were observations of both species foraging in separate flocks but in the same small group of trees (mixed observations). The two macaw species were observed foraging side by side in three separate areas of BA island, flocks of only one species were recorded in two areas of BA reserve.

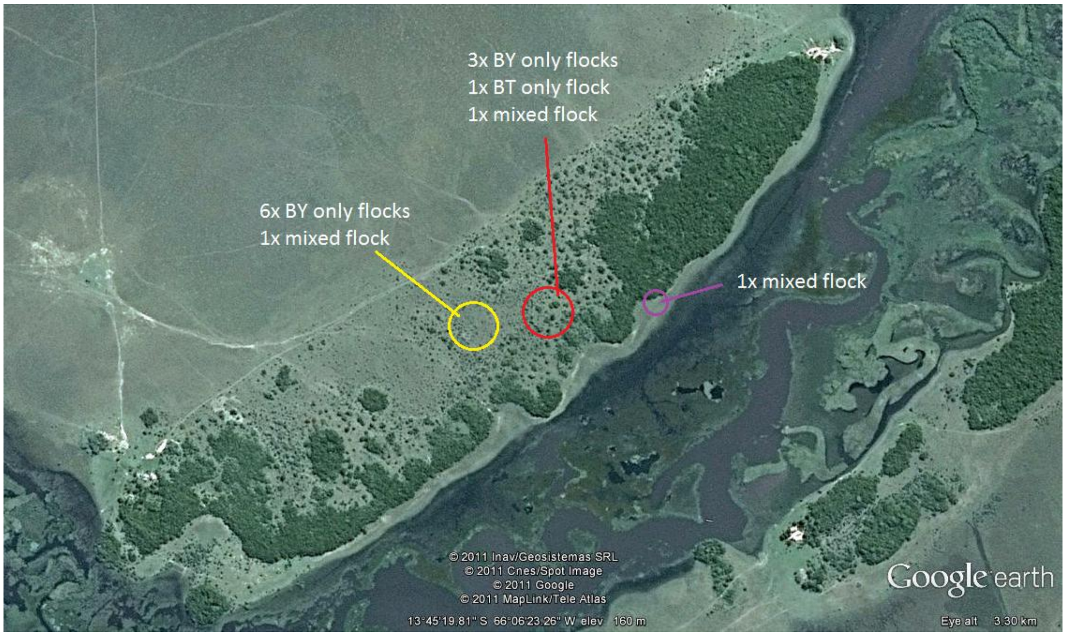

Figure 4.6: The locations within BA island where each species was recorded foraging. 'Mixed flock' refers to when both species were recorded foraging in the same small area at the same time but where not necessarily interacting. (Adapted from Google Earth maps).

4.3.1. Other Behavioural Observations: Several other behavioural observations were made which were not related to foraging. Throughout the study both macaw species were seen perching together in the same tree 8 times but only once were they observed physically interacting. On 14/8/11 at 10:05am one Blue-throated Macaw flew in and perched next to a group of Blue and Yellow Macaws. One Blue and Yellow Macaw immediately showed aggression towards the Blue-throated Macaw who retaliated. Beak snapping, wing flapping and squawking calls were observed from both individuals. This interaction only lasted around fifteen seconds, then the agnostic behaviour stopped and both birds perched still on the tree.

When the macaws were scared off by field workers both species reacted differently. Blue and Yellow Macaws were found to be more forward and aggressive than Blue-throated Macaws, as many times they were recorded circling the field workers overhead, swooping down low and repeatedly calling out in the raspy tone characteristic of this species. On the other hand Blue-throated Macaws showed a different behaviour, when disturbed they quickly flew off making high pitched, shrill sounds. When one member of either species flew off due to disturbance the rest of the macaws of the same species (and sometimes several of the other species) flew off along with it.

Of all 33 ten minute individual behaviour observations recorded 22 (66.7%) of these ended before the ten minute period due to the subject flying off, usually due to the presence of the field workers, and for this reason no time budget studies were carried out on this data.

Throughout the observational study both species were found, for the majority of the time, perching in pairs or groups of three individuals (possibly two adults and a juvenile) within a larger group on perennial woody trees.

4.4 *Attalea phalerata* Palm Nut Study

To examine the possibility that Blue-throated and Blue and Yellow Macaw forage together/in the same area the species specific marks left in the mesocarp of *Attalea phalerata* palm nuts were examined. Out of the 16 samples collected 7 contained nuts with Blue-throated Macaw marks only, 6 with Blue and Yellow Macaw marks only and 3 samples had a mixture of nuts consumed by both species (Figure 4.7). Of these samples 11 were given the freshness rating of 1 as described in the methods section of this report: all samples containing Blue-throated Macaw nuts only, 4 samples containing Blue and Yellow Macaw nuts only and 1 of the 3 mixed samples. Freshness rating 2 was given to 2 of the Blue and Yellow Macaw only samples and one mixed sample and rating 3 was only given to one mixed sample. Whether the macaw species which ate the *Attalea phalerata* nut was seen at the recording site was also noted down (Table 4.6).

Sample Number	**Number of *A. ararauna* nuts present.**	**Number of *A. glaucogularis* nuts present.**	**Macaws observed (Y/N)**	**Freshness Scale (1-3)**
1	18	0	Y	1
2	13	0	Y	1
3	0	8	Y	1
4	0	3	N	1
5	28	0	Y	1
6	0	2	N	1
7	32	0	N	2
8	25	0	N	2
9	20	13	N	2
10	1	3	N	3
11	3	1	N	1
12	11	0	Y	1
13	0	11	Y	1
14	0	38	N	1
15	0	26	N	1
16	7	0	Y	1

Table 4.6: Summary of the A. phalerata palm nut data collected. The number of nuts collected as well as whether or not A. ararauna or A.glaucogularis was seen foraging when the sample was taken. (n=16).

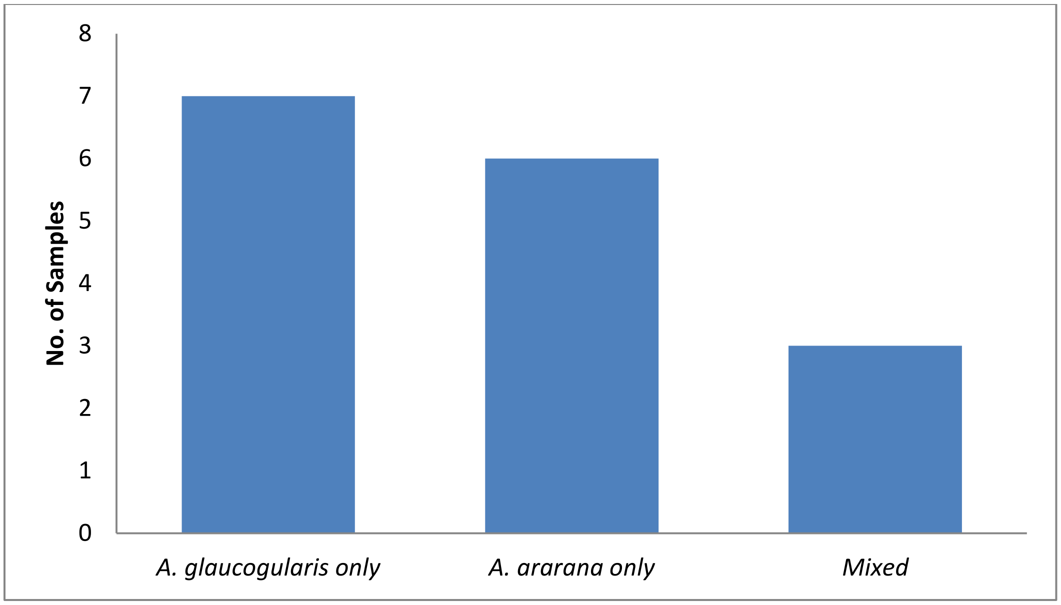

Figure 4.7: The number of samples which contained Attalea phalerata palm nuts consumed by A. glaucogularis only, A. ararauna only and those samples which contained both. Note that there are far fewer samples containing mixed nuts than those of one species only (n=16).

For half the samples (8 out of 16) the observer saw one of the two species (or both) foraging on the *A. phalerata* palm moments before the sample of nuts was collected from underneath it. These visual sightings all corresponded with the markings on the nuts collected i.e. If a Blue and Yellow Macaw was seen foraging on the palm then nuts collected had the characteristic markings thought to be caused by that species.

There was no significant statistical difference between the width of the nuts consumed by each species (P=0.297, R-sq=3.75%) but there was significant variance between the length of the nuts (P <0.001, R-sq=43.11%) (Tables 4.7 and 4.8).

Source of variation	Sum of Squares	df	F	P	Parameter estimate	Standard Error
Species	328.78	1	21.97	<0.001	BTM=-3.2583	0.69518
Error	433.93	29				
Total	762.71	30				

Table 4.7: Summary of the GLM results looking at whether the Length of the Attalea phalerata palm nuts collected is related to the species believed to be eating them. Results indicate that there is a significant difference in nut length between species.

Source of variation	Sum of Squares	df	F	P	Parameter estimate	Standard Error
Species	8.672	1	1.13	1.297	BTM=0.5292	0.4980
Error	222.683	29				
Total	231.355	30				

Table 4.8: Summary of the GLM results looking at whether the breadth of the Attalea phalerata palm nuts collected is related to the species believed to be eating them. Results indicate that there is no significant difference in the breadth of nuts between species.

Boxplots (Figures 4.8 and 4.9) illustrate the size range of the *A. phalerata* palm nuts consumed by both macaw species. There does not seem to be any substantial variation in the breadth of palm nuts between species (agrees with GLM analysis), the range of sizes is relatively similar between species. There seems to be some overlap in length between species but on average it seems that Blue-throated Macaws tended to utilise nuts which were shorter in length than the Blue and Yellow Macaws. No extreme outliers were recorded.

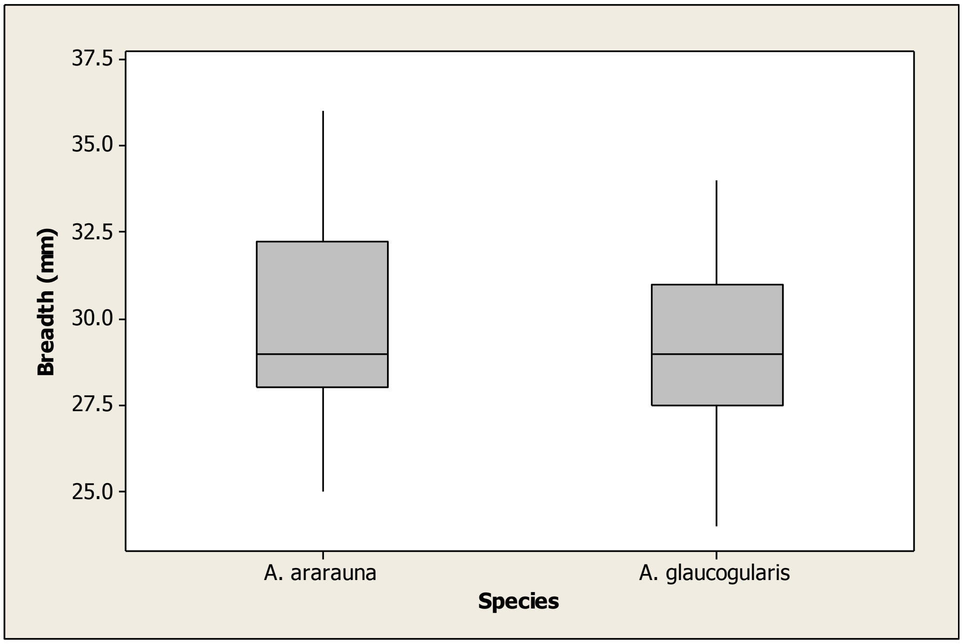

Figure 4.8: Boxplot of the range of breadths of A. phalerata nuts consumed by A. glaucogularis and A. ararauna. It shows a lot of overlap in the breadth of nuts between species.

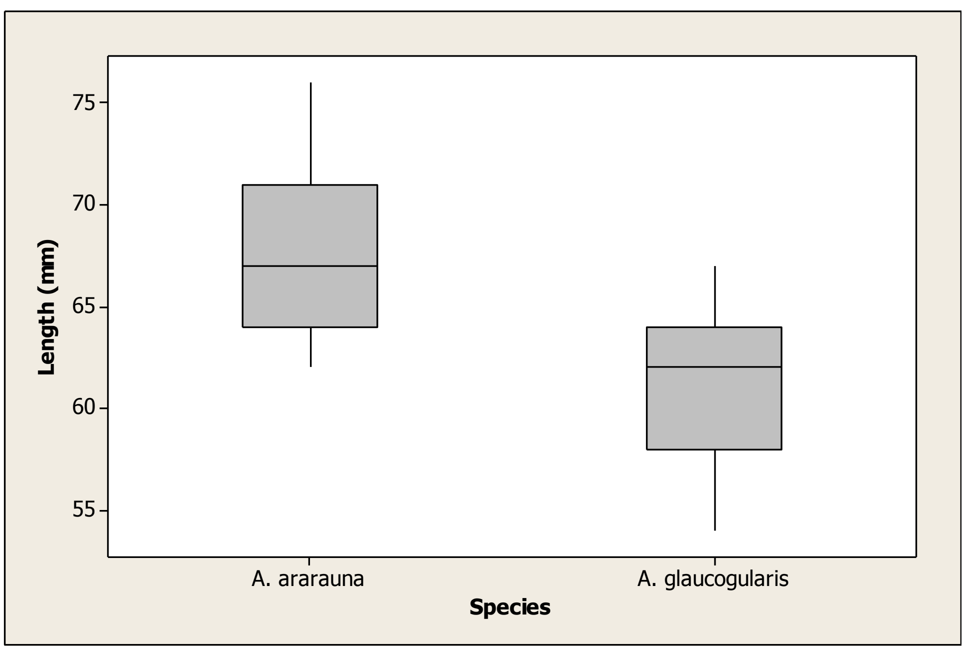

Figure 4.9: Boxplot of the range of lengths of A. phalerata nuts consumed by A. glaucogularis and A. ararauna. It shows much less overlap than that seen in the breadth of nuts between species.

4.5. Botanical Survey

The largest number of *Attalea phalerata* was recorded in BA island (n=74) making up 78% of all trees recorded across the five transects (Table 4.9). *A. phalerata* made up less of the tree composition in LM and FO islands with only 65% and 45% respectively. In certain areas of the forest islands *A. phalerata* was patchily distributed, occurring in large numbers in some areas and few in others. For example in LM island transects 1 and 4 both recorded 21 *A. phalerata* whereas in transect 3 only 1 was recorded.

Island	Transect/ Total for each island	No. *A. phalerata*	No. other Arecaceae	No. other trees	% *A. phalerata*	No. Fruiting *A. phalerata*	% fruiting *A. phalerata*	Average Height *A. phalerata* (m)	Average DBH *A. phalerata* (cm)
BA	1	12	1	6	63	9	75	25.6	43.2
	2	13	0	0	100	10	77	29.7	46.7
	3	17	0	0	100	16	94	34.1	42.5
	4	13	0	2	87	14	61	34.5	38.3
	5	19	0	2	90	8	74	38.3	37.8
	Total	**74**	**1**	**10**	**87**	**57**	**77**	**33.1**	**41.4**
LM	1	21	0	4	84	15	71	19.2	44
	2	11	0	13	46	9	81	26.5	42
	3	1	0	7	13	1	100	27	39
	4	21	1	1	91.	19	90	25.6	34
	5	13	0	10	57	8	62	20.3	38.5
	Total	**67**	**1**	**35**	**65**	**52**	**78**	**22.8**	**39.4**
FO	1	7	0	22	24	5	71	31	37
	2	28	1	2	90	13	46	2.7	44.6
	3	18	1	9	64	4	22	3.4	46.9
	4	3	0	21	13	0	0	10.7	38.3
	5	7	0	21	25	1	14	5.1	36.1
	Total	**63**	**2**	**75**	**45**	**23**	**37**	**6.7**	**43.2**

Table 4.9: Summary of the botanical survey carried out across all three forest islands. Information for each individual transect is given as well as that for the island as a whole.

A. phalerata appears to be the dominant palm across all three forests as only one other species from the family Arecaceae was recorded, *Acrocomia aculeate* (only 1 specimen was recorded in BA and LM, only 2 in FO).

To analyse any difference in height and DBH of *A. phalerata* across the forest islands GLMs were used (Tables 4.10 and 4.11). There was a significant difference in the height between the forest islands (P<0.01), but no significant difference in DBH (p=0.095), indicating that DBH does not differ greatly according to forest island.

Source of variation	Sum of Squares	df	F	P	Perimeter estimate	Standard Error
Island	23863	2	139.51	<0.001	BA=12.2500	0.8980
					FO=-14.1511	0.9347
Error	17191	201				
Total	41054	203				

Table 4.10: Summary of the GLM results looking at whether height of Attalea phalerata differs across the three forest islands. The result indicates that there is a significant difference in height between forest islands (R-sq=58.13%)

Source of variation	Sum of Squares	df	F	P	Parameter estimate	Standard Error
Island	482.2	2	2.38	0.095	BA=0.0731	0.9766
					FO=1.888	1.016
Error	20331.4	201				
Total	20813.5	203				

Table 4.11: Summary of the GLM results looking at whether DBH differs across the three forest islands. The results indicates that there is no significant difference in DBH between forest islands (R-sq=2.32%)

There was a difference in the number of fruiting *A. phalerata* across the forest islands. Figure 4.14 shows the percentage which were fruiting (across the whole forest island) at the time of recording. Islands BA and LM have had similar numbers of fruiting motacus, 77% and 78% respectively, but FO had much less with 37% overall.

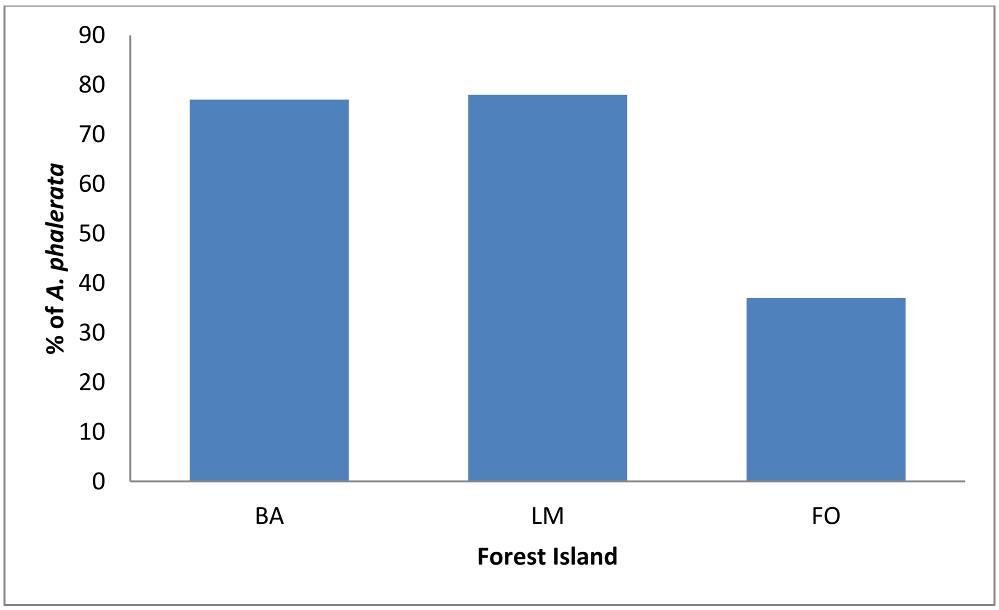

Figure 4.14: The percentage of A. phalerata which were fruiting in the three forest islands during the botanical survey.

In BA island there was some difference in the number of fruiting motacus recorded across the different transects (Figure 4.15). Transects 3 and 4 had the most fruiting trees (n=16 and n=14 respectively) whereas transects 1, 2 and 5 had less (n=9, n=10 and n=8 respectively). The percentage of fruiting *A. phalerata* was high throughout all transects in this island, ranging from 61% to 94% of all *A. phalerata* palms (Table 4.8).

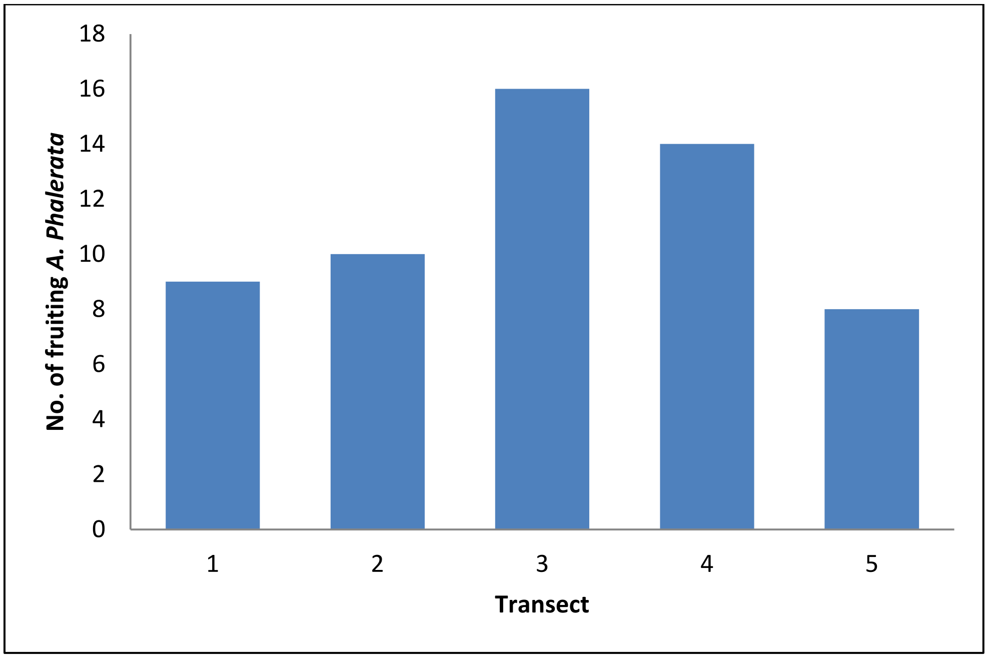

Figure 4.15: Shows the number of fruiting A. phalerata recorded in each transect in BA island.

4.6. The effect of Weather

General linear model (GLM) analysis on the individual island point count data (where the most weather variation was seen) showed that the drastic change in weather conditions had no significant effect on the number of macaws flying over or leaving the islands (For flying over P=0.649 and R-sq= 0.25%, for leaving p=0.161 and R-sq= 2.38%). The GLM outputs are summarized in Tables 4.12 and 4.13 below.

Source of variation	Sum of Squares	df	F	P	Parameter estimate	Standard Error
Weather	605	1	0.21	0.649	Cold/wind= 2.971	6.496
Error	237282	82				
Total	237887	83				

Table 4.12: A summary of the GLM results investigating whether or not the number of macaws that flew over the forests islands during the individual point counts was affected by differing weather conditions. The non-significant result suggests the weather conditions did not affect the number of macaws that flew over the forest islands.

Source of variation	Sum of Squares	df	F	P	Parameter estimate	Standard Error
Weather	610.3	1	2.00	0.161	Cold/wind=-2.983	2.110
Error	25026.0	82				
Total	25636.3	83				

Table 4.13: A summary of the GLM results investigating whether or not the number of macaws leaving the forests islands during the individual point counts was affected by differing weather conditions. The non-significant result suggests the weather conditions did not affect the number of macaws leaving the forest islands.

5. Discussion

A minimum of 52 Blue-throated Macaws and 398 Blue and Yellow Macaws were recorded using the Barba Azul Nature Reserve. Many more Blue and Yellow Macaws utilised this area than Blue-throated Macaws, which are outnumbered by Blue and Yellow Macaws by a factor of 7.6. If the current population estimate of 200 wild Blue-throated Macaws is correct (Strem, 2008; Yamashita and Machado de Barros, 1997) the number recorded on the reserve represents more than 25% of the current wild population, highlighting the reserves importance in the conservation of this endemic species. Both species utilised BA island to the greatest extent (Blue-throated Macaw: n=30, Blue and Yellow Macaw: n=133) indicating that this forest island is different from LM and FO islands in some way. The reserves conservation priority should be conserving the Blue-throated Macaws already utilising the reserve whilst implementing measures to regenerate the Juvena section (reduce disturbance from cattle etc.) in order to encourage more macaws into this area.

The species specific marks left in the mesocarp of *A. phalerata* nuts consumed by the two macaw species allows identification of which species ate the nut even if the bird itself is not seen. This could be used to identify new foraging grounds of the Blue-throated and Blue and Yellow Macaw in the future, without having to track the birds over large distances. Both species were found to forage in the same areas of BA island but we were unable to tell if they foraged together at the same time.

5.1. Minimum Population Size Estimation

A minimum number of 52 Blue-throated Macaws and 398 Blue and Yellow Macaws were recorded utilising the Barba Azul Reserve during this study. For the Blue-throated Macaw this number is almost exactly half of that recorded by the University of Glasgow Bolivia Expedition (2010) in the previous year (n=103). It is possible that the large number recorded in 2010 was a fluke or a miscount during the data recording. However this seems unlikely as three times (over 12 point counts) during the study more than 70 Blue-throated Macaws were recorded leaving or flying over BA island alone (University of Glasgow Bolivia Expedition Report, 2010).A more plausible explanation for this is that a large number of Blue-throated Macaws which were recorded on the reserve previously are now utilising a different foraging ground (perhaps one which is closer to their roosting site or has less competition from Blue and Yellow Macaws) or that the number of Blue-throated Macaws in the area has dramatically decreased over that last year. Without further study in the areas surrounding the Barba Azul Reserve the reason for this decline will remain unknown.

In the previous year the University of Glasgow Bolivia Expedition calculated the minimum number of Blue-throated Macaws on the reserve to be 284 (Glasgow University Bolivia Expedition Report, 2010), much less than the number recorded in this study (n=398). There are several reasonable explanations for this including that the 2010 study focused only on BA island, leaving out FO and LM, as the sale of the Juvena ranch to Association Armonia was only just being finalized. Adding these two islands into this study meant that the macaw population was recorded over a wider geographical area and reflects a larger part of the reserve than that used in 2010. This has increased the number of Blue and Yellow Macaws recorded during this study as many individuals were found utilising the new Juvena section of reserve.

When leaving the forest islands to roost at sundown the vast majority of the two species flew off in a northerly direction (N, NE, NW) which agrees with the results obtained by the 2010 expedition. This indicates the likely direction of the roost sites of the Blue-throated and Blue and Yellow Macaws using the reserve. A proportion of Blue and Yellow Macaws are known to roost in several of the smaller islands in the north of the reserve but little is known about where exactly these Blue-throated individuals roost, except that it is not believed to be within the reserves boundary (Mauricio Herrera, personal comment).

There was a large variation in the number of the two macaw species recorded across the 3 island point counts. The number of Blue-throated Macaws recorded ranged from 9 to 52, and the number of Blue and Yellow s recorded ranged from 199 to 398. It was originally hypothesised by the field workers that this variation was down to changes in weather throughout the six week study. This hypothesis was proven to be unfounded when GLM analysis showed that there was no significant difference between the number of either species leaving or flying over the forest islands on days of cold rainy weather compared to those of hot dry weather ($P=0.649$) (Tables 4.12 and 4.13). The count on 02/08/2011 was the only total point count recorded cold/windy conditions (Figure 4.1) and it is clear that the number of both macaw species recorded on this day is similar to those recorded on days when the weather was dry and sunny.

If weather conditions do not seem to affect the number of either species on the reserve then why was the number of macaws so variable? Little is currently known about the behaviour of these species therefore it is difficult to come to any solid conclusions in relation to where they are foraging. Perhaps they alternate between different foraging sites on a daily or weekly basis depending on which area has the most fruiting *Attalea phalerata* palms. The breeding season of the Blue and Yellow Macaw begins around late October/early November, so perhaps towards to end of the study the presence of Blue and Yellow Macaws decreased because they were preparing for the mating season and hence were foraging closer to their nesting grounds. These possible explanations are tentative hypotheses and are not based on scientific data.

5.2. Individual Forest Island Utilisation

There are several possible explanations as to why both macaw species utilised BA island to the greatest extent. Firstly Barba Azul island was shown to have the highest number (and percentage) of *A. phalerata* palms compared to the other two islands (n=75, 87% of all tree species recorded). Since this tree species is a fundamental requirement of macaws in this area its abundance in the forest islands is likely to influence the number of macaws foraging there. Secondly the *A. phalerata* recorded in BA island were found to be significantly taller ($p<0.01$) than those in LM and FO (Table 4.9). Perhaps these macaws prefer to forage on larger trees as they feel safer higher up and away from predators on the forest floor. Throughout the study no macaws were seen foraging on the ground, perhaps staying high up in the trees for protection, further supporting this theory. Thirdly BA island had the highest number of fruiting *A. phalerata* palms (n=57) which is the main attraction of these trees for the macaws. However, LM island was recorded to have 52 fruiting *A. phalerata* palms, not considerably less than BA, but the macaw numbers here were substantially lower (Table 4.5). It is reasonable to suggest that perhaps there were other influences, unrelated to *A. phalerata,* which influenced forest island utilisation.

BA island is situated in the original Barba Azul Reserve (Figure 3.2) which has been protected for a longer period of time than the recently acquired Juvena section. It is therefore subject to far less disturbance from human activities and there are fewer cattle in this area to cause habitat alteration (only cattle which have escaped from neighbouring ranches). Perhaps disturbance is affecting the number of macaws utilising the islands in the Juvena section, especially LM island as the new tourist lodge is situated within 10 metres of its boundary.

At first glance forest island size seems like a plausible explanation for the number of macaws utilising each island. Most Blue and Yellow and Blue-throated Macaws forage in BA island which had the biggest area ($1368000m^2$), and the lowest numbers were recorded in LM island, which has the smallest area ($332979m^2$). However from Figure 4.6 both macaw species forage repeatedly in the same small areas within the large BA island and are not spread out evenly throughout it. There is not enough evidence in the study to say whether or not forest island area influenced forest island utilisation however it is logical to presume that the larger the forest island the larger number of fruiting *A. phalerata* palms on average, the macaws main attraction to the forest islands.

When looking at the specific foraging locations of the two species within BA island (Figure 4.6) it is apparent that the areas both species were recorded foraging in are the areas with the highest number of fruiting *A. phalerata* palms. BA island botany transects 3 and 4 were located in the same areas as both species were recorded foraging in (red and purple circles in Figure 4.6) and had a total of 16 and 14 fruiting *A. phalerata* palms respectively. It therefore seems that both macaw species will cluster together and forage in areas within the forest island which have the highest abundance of fruiting *A. phalerata* palms. This information only covers 13 of the 19 foraging observations recorded due to an error by fieldworkers, this may have had some effect on the results. However I was present during all foraging behaviour study sessions and it was obvious at the time that both macaw species were foraging repetitively in certain parts of BA island. This reason is perhaps the most influential in determining which areas the two macaw species utilise as it involves food, a resource required by all living things.

The Blue-throated Macaw did not appear to utilise LM and FO islands even though the Blue and Yellow Macaw did. Perhaps the main reason Blue-throated Macaws did not utilise FO was due to the high number of Blue and Yellow Macaws in this area therefore competition may have been too great. Blue and Yellow Macaw numbers were also high in BA island but competition was probably less of a concern there as food resources are far more abundant. The group of Blue-throated Macaws which forage there stayed in relatively large numbers (usually >10) and were well established within the area.

The largest number of Blue and Yellow (n=201) and Blue-throated Macaws (n=28) were recorded leaving around stationary point 3 of BA island (Figure 4.3). This may be because this is the most northerly point of the island and north was the direction in which most Blue-throated and Blue and Yellow Macaws flew off in. On the other hand it could be due to this area of BA island being the least disturbed by human activity therefore a safe place to congregate. It was noticed by the field workers that both species seem to gather there on the outskirts of the island in large groups, perhaps for protection, before flying off to their roosting sites.

5.3. Foraging Behaviour study

There has so far been little investigation into the foraging behaviour, and other behaviours, of the Blue-throated Macaw but in this study it was noticed that the behaviours of both species were remarkably similar.

The Blue-throated Macaw was recorded eating the fruit of *Attalea phalerata* only once whereas Blue and Yellow Macaws were recorded a total of six times, all in the species specific ways described in the results section. It is hypothesised that these methods are those consistently employed by each species in order to consume the palm nuts most efficiently. The species specific marks go some way in confirming this idea. In order to say with complete certainty that Blue-throated Macaws consume the motacu nut in the way described more observations should be made during a future study. There were far more Blue and Yellow Macaws in the area than Blue-throated therefore it was anticipated that more observations of Blue and Yellow Macaws would be recorded (this also applies throughout the rest of this study). Perhaps more focus should have been placed on recording the foraging behaviour of Blue-throated Macaws in order to accommodate for the difference in species number.

The two macaw species were not recorded eating any other plant materials other than the mesocarp of the *Attalea phalerata* palm nut. Other studies have recorded Blue-throated Macaws feeding on the seeds, fruits, flowers and stems of eight other plant species including *Acrocomia aculeata* and *Hura crepitans*, however they agree that the motacu palm fruit is the most important and abundant constituent of their diet (Yamashita and Machado de Barros, 1997; Hesse, 2000). One foraging observation which was not witnessed during this study is described by Jordan and Munn (1992). Blue-throated Macaws were recorded occasionally opening up the fruits of immature *Attalea phalerata* palms and drinking the liquids within them. One source suggests that the reason they may consume unripe nuts is to gain a 'competitive edge' over mammals which disperse the fruits over a wide area (Hoyo *et al*. 1997). Perhaps this behaviour was not witnessed in this study as palm nuts were plentiful and competition with mammals was low in the area allowing Blue-throated Macaws to consume only ripe nuts. On the other hand it is possible that this behaviour is just exceptionally rare and if this study was expanded we may have recorded this behaviour.

One of the primary aims of this study was to work out if there was any temporal difference in foraging behaviour. Results suggested that the majority of foraging took place during the afternoon hours (recorded between 11:00am and 2:00pm) with four Blue-throated and seven Blue and Yellow Macaw observations made throughout these sessions (Figure 4.5). Numbers of both species recorded in the morning and evening studies were much less than those recorded in the afternoon period. As the afternoon hours are the hottest time of the day it is reasonable to presume that during this time both species would be likely not to forage and perch in the sun saving valuable energy; however this does not seem to be the case here, perhaps because the majority of the influcoscenes are shaded under the canopy. Whilst the morning studies were being carried out a number of Blue-throated and Blue and Yellow Macaws were still flying into BA island from their roosting sites, so perhaps less were recorded foraging in the morning is due to less macaws actually utilising the island at that time of day. During the evening study sessions the two species appeared to be restless, gathering together in larger flocks at pre departure sites before leaving BA island, and foraging did not seem to be a priority. Maybe it is for these reasons that the macaws forage the most in the afternoon, they have to make the most of the foraging time that they have before they fly off again to roost in the evening.

Out of all 33 ten minute individual observations 22 ended before the ten minute period had finished. This may be due to the fieldworker scaring the macaws away or perhaps the natural behaviour of these two macaw species is to perch in one tree for several minutes and then fly off to another tree nearby. Further study in needed to confirm this finding.

Both macaw species spent a great deal of time perching still in the trees (the majority of the time they were not foraging). Studies on the Red-fronted macaw (*Ara rubrogenys*) revealed that they spend 35-65% of their time during the day resting, perching for periods of several hours whilst carrying out interspaced behaviours such as autopreening and playing (Pitter and Christiansen, 1997). Findings in this study lean towards similar conclusions, both Blue and Yellow and Blue-throated Macaws were recorded perching for lengthy amounts of time in the sun whilst periodically taking part in other defined behaviours (Table 3.2).

Little direct interaction was recorded between the two species- they perched together in the same trees and foraged in the same areas but only once were they seen directly interacting. Literature suggests that competition between these two sympatric species is one of the reasons Blue-throated Macaw numbers are so low today (Hesse, 2000) but in this study both species appear tolerant, and even somewhat respectful, of each other's presence. It is possible that if resources were scarcer in this area there would be an increase in competition, and hence an increase in agnostic encounters between these species.

According to Duffield and Hesse (1997) Blue-throated Macaws are never seen in large flocks but in this study flocks of up to twenty individuals were recorded during the point count surveys. Maybe the reason that large flocks have never been recorded is because they are not usually found in such high abundance as they are on the Barba Azul Reserve. Small groups came together to fly to their roosting grounds in a similar way to the Blue and Yellow Macaw, perhaps for protection and security in numbers. Several times during the point count study mixed flocks of the two macaw species were seen leaving the BA island together and flying northwards to roost. This suggests that both species might have a communal roosting area somewhere to the north of the reserve. In order to confirm this permission from neighbouring ranches must be granted and studies must take place there to find this potential roosting site.

It was difficult to get close enough to the Blue-throated and Blue and Yellow Macaws to observe their behaviours as both were easily disturbed by field workers and would quickly fly off when frightened. It quickly became evident that the presence of humans can alter the behaviour of both species even if the best preventative precautions are taken, therefore observations were noted down quickly and quietly in order to be representative of the natural behaviour of both species.

5.4. *Attalea Phalerata* Palm Nut Study

From observations during the foraging behaviour study it was noticed that both macaw species held *A. phalerata* palm nuts differently when eating them and consumed them in a different way (as described in the results section, Figure 4.4) leading to different characteristic marks in the fruit's mesocarp. It is hypothesised that this was due to the Blue-throated Macaw having a specialized modification of its beak which Blue and Yellow Macaws do not have. Blue-throated Macaws have a narrower chisel-like beak with a longer lower jaw than Blue and Yellow s (Yamashita and Machado de Barros, 1997) which is perhaps used for better grip around the nuts breadth leading to these 'spin tracks' being scraped into the flesh. It is likely that this specialised beak is an adaptive trait which has evolved for more efficient consumption of this particular palm nut since it is the primary food source of this species, whereas Blue and Yellow Macaws do not have this adaptation as they are more general foragers.

The lengths and breadths of a small sample of *Attalea phalerata* nuts were recorded in order to determine whether the size of the nut influenced which species of macaw consumed it as. If a correlation was found it could it could explain the difference in characteristic markings. GLM analysis indicated no difference between the breadth of the nuts consumed by each species ($p=0.297$) but did indicate a significant difference in the lengths ($p<0.001$) suggesting that Blue and Yellow Macaws tends to consume longer palm nuts than Blue-throated Macaws. It was suggested by staff at Association Armonia that the size difference of the nuts is what caused the two species to consume the nuts differently and that if a Blue and Yellow Macaw 'chose' to eat a nut shorter in length it would consume it in a similar way to that of the Blue-throated Macaw recorded in this study (Mauricio Herrera, personal comment). It is unlikely that these nuts vary enough in size to warrant the evolution of two separate consumption modes which have the same overall outcome. Time and resources would be wasted on deciding which way to consume a palm nut when both methods are likely to be sufficient enough for the range of nut sizes available. As described in the results section Blue and Yellow Macaws scrape the flesh from the palm nut by putting their whole beak (upper and lower parts) over the end of the nut and scraping upwards creating subtle lengthways indents in the mesocarp (Figure 4.4). Logically it would seem more beneficial if they ate nuts of shorter length so they can reach further down the nuts length with their beak to consume it easier and faster, not the longer ones as these results suggest.

From the samples of nuts collected it could not be determined if Blue-throated and Blue and Yellow Macaws forage together at the same time as two out of the three samples collected containing nuts consumed by both species were too old to confirm this (Freshness rating of 3). Freshly eaten nuts collected under a single motacu tree tended to only have the marks of one species but other trees in close proximity had nuts from the other species only. It seemed that the two macaw species were utilising the same groups of *Attalea phalerata* palms because these groups were the ones which were in fruit rather than actively choosing to forage together in a mixed flock (foraging observations agree with this).

Why is *Attalea phalerata* so important to the Blue-throated Macaw even though there are other food sources in the Beni savannah which it could utilise? One of the main reasons is that it is known to be continuously fruit productive all year round (Hesse, 2000) which suits these non-migratory birds. The fruit reaches maturity in less than 30 days and each influcoscene holds 350-500 fruits making this a plentiful food source for these macaws (Moraes and Beck, 1997*)*. It is the most abundant palm of the forest islands in the Beni, especially in areas common to disturbance such a fire as it is an extremely fire resistant species (Langstroth, *in prep*) therefore reliable in the Beni where annual burning of the grasslands is common. The mesocarp of these palm nuts is also highly nutritious and high in fats and carotenoids (Moraes and beck, 1997; Yamashita and Machado de Barros, 1997). It is likely that a combination of these reasons have led to Blue-throated Macaws relying on this tree species above all others in the Beni savannah.

5.5. Conclusion

Blue-throated Macaws and Blue and Yellow Macaws behaved in a remarkably similar way throughout this study. This is not surprising as these two species are closely related (Family Psittacidae) and share the same habitat which fulfills the same ecological requirements of both species. For example, similarities in temporal foraging behaviour are due to the repetitive daily behaviour pattern of both species which comprises of flying into these forest islands in the morning, foraging as much as possible during the daylight hours, and then flying back to their roosting sites before dusk. From this information scientists can perhaps aim to protect both of these species, but in particular the Blue-throated Macaw, using the same, or similar, conservation objectives.

A minimum of 52 Blue-throated Macaws and 398 Blue and Yellow Macaws were found to be utilising the reserve. If the population estimate of only 200 wild Blue-throated Macaws (Strem, 2008; Yamashita and Machado de Barros 1997) still currently applies then over 25% of the world's wild population are using the Barba Azul Reserve to some extent, highlighting its importance in the conservation of this species. The number of Blue-throated Macaws recorded in this study is less than the number recorded on the reserve in 2010 (Glasgow University Bolivia Expedition Report, 2010). Association Armonia should now look closer at why their number has decreased, and how to increase this number in future years.

The number of Blue-throated and Blue and Yellow Macaws recorded on the Barba Azul Reserve cannot be considered as representative of the total wild population in Bolivia. The number of Blue-throated Macaws has declined on the reserve but this report provides no evidence to suggest that this trend is reflected across the entire Beni savannah. An up to date account of the numbers of this species left in the wild is needed before any conclusions can be drawn about the current population status of this species. The findings produced here will help Association Armonia protect both macaw species on the Barba Azul Nature Reserve in coming years.

In the last twenty years papers have been published by scientists such as Jordan and Munn (1992), Yamashita and Machado de Barros (1997) and Hesse (2000) which have provided a background on the ecology of the endemic Blue-throated Macaw, serving as a basis for this particular study and studies in future years. Future research should focus on learning as much as we can about Blue-throated Macaws and Blue and Yellow Macaws, in order to protect them in their natural habitat.

On the Barba Azul Reserve, future work should concentrate on further explaining why Blue-throated Macaws are not utilising the Juvena section to the same extent as it is the older Barba Azul section. Once more information about this is known, it will be possible to set up a program ro encourage more Blue-throated Macaws to use this area by protecting the resources needs most. Once the cattle have been moved out of this area and land management objectives are introduced it is hoped that the area will regenerate to a similar condition to that of the original part of the reserve north of the Rio Omi, which will in turn attract more Blue-throated Macaws to the area.

The University of Glasgow Bolivia Expedition will continue to conduct annual studies on the reserve, estimating the minimum population size of the Blue-throated Macaw and Blue and Yellow Macaw using the area on a yearly basis. This means that any decreasing population trend will be noticed and action can subsequently be taken to resolve it before numbers of Blue-throated Macaws become critically low. Having a yearly population count will also tell Association Armonia if their management objectives are working effectively.

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Gerard Hoffman, Blue and Yellow Macaw, Available at: http://nationalzoo.si.edu/scbi/migratorybirds/featured_photo/bird.cfm?pix=Blue-and-yellow_Macaw

*Cover photograph from Langstroth (*in prep*)

7. Appendices

Provided on the disc attached to this report.