Estimating Population Status and Distribution of the Critically Endangered Blue-throated Macaw (*Ara glaucogularis*) and Comparisons to the Sympatric Blue and Yellow Macaw (*Ara ararauna*) in the Barba Azul Reserve, Bolivia

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Abstract:

The Blue-throated Macaw(*Ara Glaucogularis*) is one of the worlds's most threatened bird species and like other parrot species faces many threats to extinction. The wild population is currently estimated by the IUCN to consist of between 73 and 87 adults. This project was carried out in the Barba Azul Reserve in Bolivia, home to a large population of Blue-throated Macaws and Blue and Yellow Macaws (*Ara ararauna*). Surveys were completed on the population size, roosting behaviour and Blue-throated Macaw flight behaviour, along with surveys of the habitats used by both species. Results documented a minimum of 490 Blue and Yellow Macaw and 111 Blue-throated Macaws that utilise the reserve, suggesting that the global population is considerably larger than previously thought. Similar to other macaw species, they exhibit communal roosting. A large proportion of Blue-throated Macaws were observed flying northerly, indicating roost site location. Blue and Yellow Macaw had a distributed flight direction, signifying variation in roost sites. Measurements of the Blue-throated Macaw flight speed indicated an average speed of 50.8Km/hr, indicating the theoretical distance to roost sites. One forest island was observed with 59 individuals utilising it. Multiple roost sites were found for the Blue and Yellow Macaw. The abundance of fruiting Motacu palms were also documented. Certain areas have significantly reduced regeneration, indicating possible future problems conserving the macaw species. It was concluded an estimate of the reserve macaw population size could be found. Further recommendations for Asociacion Armonia will be regular population counts, and the removal of cattle, vital in allowing the Motacu to regenerate.

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1. Introduction

1.1. Reasons to Conserve Macaws and other Parrots

Parrots are believed to be the most endangered family of birds in the world, with 26% of the family is at risk of extinction (Jurgen, Del Hoyo and Sargatal, 1997).

However, it is widely known that Parrots are very important for the ecosystems that they inhabit due to their foraging behaviour. They are mostly frugivorous and therefore are great dispersers of seeds throughout their environment. This is very important for tree distribution throughout the habitat, and reduces competition with the parent tree. It is believed that in the neotropics, larger frugivores can contribute to 60-75% of seed dispersal (Strahl and Grajal et al, 1991). The studying of the ecology of these large birds is crucial in understanding habitat management and protection due to their important ecological roles, and their contribution to neotropical ecosystem maintenance.

1.2. Threats to Macaws and other Parrots

The effect of habitat destruction will certainly be having a grave impact on parrot populations worldwide due to their lower fecundity and their larger size (Mckinney and Lockwood, 1999). Habitat is crucial to this group since it is vital for their dietary needs and breeding/roost sites. As mentioned previously, the abundance of parrots may be an indication of the degree of the environmental impact and damage created by man.

The removal of nest sites might pose the highest risk as it slows population growth; whilst other feeding sites can be found due to the varied diet of many parrot species. Some

species depend on certain tree age classes to form nest sites so the removal could compromise population growth for many years to come.

The pet trade has also been a significant contributor to the decline in the wild populations of this order; starting in the 1960s, there is still an ongoing problem within the pet trade across the globe (Jurgen, Del Hoyo and Sargatal, 1997).

1.3. Threats to the Blue-throated Macaw

One of the study species in this report is the critically endangered Blue-throated Macaw. A major cause of the Blue-throated macaw population decline was due to the pet trade which had a grave effect on their populations worldwide. Bolivia enacted legislation in order to reduce the impact of unauthorised transport of its endemic species in October 1979(Herrera and Hennessey, 2007) and in 1984 there was a ban on any export of this species out of the country. However it is known that during the 1980's a very large number of this species had been seen passing through the U.S- numbers passing that of the current wild population (Herrera and Hennessey, 2007). It was estimated by Carlos Yamashita and Yuri Machado de Barros in 1997 that during this period over 1,200 of this macaw was transported around the world by the pet trade severely damaging the wild population in the Beni. The population of this species is thought to have diminished by 70% in the last half century, and a considerable amount since it was discovered as a wild species in 1992(Herrera and Hennessey, 2007). It is now believed that there may only be 73-87 mature individuals left (BirdLife International Species factsheet: *Ara glaucogularis*, 2014). However this is possibly underestimated and this study aims to understand the

population in the Barba Azul Reserve- which houses the largest population. In Bolivia, the pet-trade is a grave risk to the survival of this species. In Santa Cruz de la Sierra, many people have been arrested due to the trafficking of these parrots, and those found guilty serve a 2 year prison sentence and a fine imposed, equal to their earnings from their illegal trading (Herrera and Hennessey, 2007). However many are getting through un-noticed, with municipal governments doing nothing and local police forces stating that it is not their priority to monitor the trade of animals (Herrera and Hennessey, 2007) A study was completed to monitor the degree of the pet trade passing through Santa Cruz – the centre of the country's illegal pet trade. Over an 11 month period it was found that 7,279 individual parrot species passed through Lo Poxos market in Santa Cruz, and this is thought be an estimate of only 20% of the pet trade happening in this city. Bolivia's geographical location is considered to hold a tactical advantage in South America's illegal pet trading, containing a large proportion of the pet trade of Peru and Brazil. Apart from the critically threatened blue throated Macaw, other endangered species have been going through this market, with 10 endangered Hyacinth macaws (*Anodorhynchus hyacinthinus*), 26 Red-fronted Macaws (*Ara rubrogenys*) another endangered species, and it was even noticed that 2 critically endangered Lears Macaws(*Anodorhynchus leari*) had passed through this market (Herrera and Hennessey, 2007).

Another threat to the Blue-throated Macaw is the habitat destruction from human impact – cattle ranchers own and utilise large areas of the region. Throughout the dry season, there is seasonal burning of the savannahs to produce fresh grass for the cattle to feed on which brings about its issues of habitat destruction. Another concern linked with the cattle

ranching is the trampling of the ground due to the high concentration of cattle. The Motacu palm (*Attalea phalerata*) provides the main food source to this species, this study aims to see the effect of the cattle abundance on the regeneration of this palm. The burning also has an effect on certain species at the heart of the savannah ecosystem, such as Greater Rhea (*Rhea Americana*), and the Maned wolf (*Chrysocyon brachyurus*).

Additionally, there is a natural threat to this species; with inter- and intra- specific competition between other macaw species which cohabit the same ecosystem. Evidence of competition for nest sites has been observed between the sympatric *A. ararauna*, but also with *A. chloroptera* and *A. macao*. With the Red and Green Macaw an Scarlet Macaw being considerably larger than the Blue-throated Macaw, with weights of 1000-1300g compared to the mere 800g of the Blue-throated Macaw , signifying that the Blue-throated Macaw could be out-competed for nest sites by the Blue and Yellow Macaw (Hesse and Duffield, 2000).

1.4. Parrot and Blue-throated Macaw Morphology and Ecology

1.4.1. Parrot Morphology and Ecology

The family Psittacidae which comprises of the "true" parrots is one of two families in order Psittaciformes, the other family being that of Cacatuidae which contains the cockatoos. The parrots originated the Mid Eocene (40mya). The Psittacidae, contains 332 species within 78 genera (Jurgen, Del Hoyo and Sargatal, 1997).

There are some distinct morphological aspects to the order Psittaciformes, one of which is the shape of their bill. For both families the bill is constructed with a smaller lower mandible and a larger curved upper mandible (Jurgen, Del Hoyo and Sargatal, 1997).

Linked to this they have a proportionately large head with short neck with muscles to power their powerful beaks. The gizzards differ in subgroups with it being weak in the Lorrinae since their diet consists of mainly nectar and pollen (Jurgen, Del Hoyo and Sargatal, 1997). However in other subgroups such as the Arinae, it's highly developed in order to cope with tough vegetable material (Jurgen, Del Hoyo and Sargatal, 1997). Macaws tend to consume seeds of many different fruits, and often of slightly unripe fruits to give them an edge of other competing species. Zygotactyl feet in macaws and other parrots help in the de-husking fruit, often perching with one foot. This differs within species, for example this can be seen in the Blue-throated Macaw (*Ara glaucogularis*) and the sympatric Blue and Yellow Macaw (*Ara ararauna*). (Personal observation).

Great variations of size and colouration is present within the order, from the large flightless Kakapo (*Strigops habroptilus*) which can have a weight of 3 kilograms to the pygmy parrots which weigh only 10 grams. Colouration normally tends to be of green for camouflage; however many species are brightly coloured such as the Scarlet Macaw (*Ara macaoI)*, to confuse predators. Dimorphism and Dichromatization changes throughout the group with Neotropic parrots not showing many differences between sexes. An example of this is in some African parrots species where they have shown that females of the species are brighter in colouration (Jurgen, Del Hoyo and Sargatal, 1997).

The habitat that species of order Psittidae inhabit is primarily forests. Some live in open habitats such as savannahs, such as the critically endangered Blue-throated Macaw. Habitats lie mostly within the tropics with a few temperate species being found in southern U.S.A and New Zealand.

The order is believed to use habitat primarily for a food source and nest/roost. It is for this reason that they suffer greatly from the threat of deforestation. Lowland tropical forests house the largest number of parrot species due to the variety of fruiting tree species. Feeding type and habitat usage is normally determined by the shape of their wings (Jurgen, Del Hoyo and Sargatal, 1997). The Blue-throated Macaw has a long and thin wing shape in order to travel long distances for foraging sites. On the other hand there are those with shorter broader wings for reduced flight in more heavily forested areas. Other factors that determine the habitat usage is that of mineral sites, such as salt licks. This will affect the distribution of these birds. Roost/nest sites also determine habitat usage as this often comprises of old tree hollows, and in many species they roost in large numbers.

Breeding in this order differs to other birds in that parrots tend to pair for life forming strong bonds. They often nest in colonies without significant territorialism, unless in very close proximity. Apart from the Kea, and Kakapo of New Zealand, all parrot species show strict monogamous behaviour and bonds are formed from various courting techniques. Nest holes are normally in hollows in trees, while some nest sites are found on cliff faces. The number of young found in parrot species varies but it is often 2-3 young individuals. For the genus *Ara* breeding occurs generally between October and March, followed by incubation and nestlings up to 4 months, after fledging the young stay with the adults for a further 2 months before separating (Jurgen, Del Hoyo and Sargatal, 1997).

1.4.2. The Ecology of Blue-Throated Macaw *Ara Glaucogularis*

The Blue-throated macaw (*Ara glaucogularis*) is a critically endangered species of parrot(Family Psittacidae) found exclusively in the northern Beni region on the Llanos de Moxos plains-otherwise known as the Beni savannah. It was first described in 1921, and in 1981 it was confirmed as a distinct species from the Blue and yellow Macaw (*Ara araruna*). (Yamashita and de Barros 1997)

Though believed to be extinct in the wild, a population of Blue-throated macaws was rediscovered in 1992(Jordan and Munn 1993). The habitat Llanos de Moxos where a population was discovered, consists of Savannahs with gallery forest and Motacu forest Islands, was found to be crucial for the population's survival. The Motacu palm (*Attalea phalerata*) provides the nut that this macaw and other parrot species (e.g. *Ara ararauna* and *Primolius auricollis*) in the region exclusively feed on (BirdLife International Species factsheet: *Ara glaucogularis*, 2014).

1.4. Habitat and food requirements of the Blue-throated Macaw

1.4.1 Llanos de Moxos

The habitat that the Blue-throated macaw inhabits is called the Llanos de Moxos and it is situated in the North East of Bolivia. It is characterised by savannah grasslands with seasonal flooding due to the habitat having a wet and a dry season. The dry season normally lasts for 2-7 months depending on whether it is an El Nino year (i.e. the cyclic climatic shift to cold and rainy conditions in this part of the world). The wet season consists of heavy rain of up to 1800mm/yr, resulting in severe flooding. It shares many of its characteristics with the amazon basin due to this flooding which is characterised by the area. Due to this seasonal flooding forest Islands appear; vital habitats for the wildlife of

this region. It covers a significant area of the Beni region covering approximately 110,000km². It is situated to the West of the Andes Mountains and South of the Lowlands of Brazil.

This region is home to many species of flora and fauna, this high biodiversity makes the region highly valuable. To date, 146 mammals have been recorded, many of which being stated as vulnerable species in the IUCN redlist (IUCN, 2014). These include Marsh deer (*Blastocerus dichotomus*) ,Maned Wolf (*Chrysocyon brachyurus*) seen in figure 1.2, and big cats such as Puma (*Puma concolor*) and Jaguar (*Panthera onca*). There is even the presence of the Bolivian River dolphin (*Inia geoffrensis boliviensis*) a subspecies of the Amazon River dolphin (*Inia geoffrensis)* a species has potential to be under threat from the impact of human activity along the river system (Reeves et al, 2013).

There is a recorded 509 species of birds have been found in this habitat with many vulnerable and endangered species. This includes Greater Rhea (*Rhea Americana*), Orinoco Goose (*Neochen jubata*), and famously the Blue-throated Macaw (*Ara glaucoglularis*). Many of these bird species such as Greater Rhea (*Rhea Americana),* and the Golden Collared Macaw (*Primolius auricollis*), occur in few other habitats; this proves that the habitat is a rich ecosystem. Seasonal flooding of this habitat there is an abundance of amphibians, reptiles and fish. It is believed that there is a good population of *Melanosuchus niger*, the black caiman (Bennet Hennessey personal comment). Though poorly known due to lack of research, there are many species of Amphibian such as *Hypsiboas calcaratus* present in this region, remaining in stagnant pools that remain throughout the dry season. There is an estimated 325 species of fish present in the Rio Mamore and other rivers in this region.

Species such as Surubi (*Pseudoplatystoma spp*), Red Piranha (*Pygocentrus nattereri)* are very common and are an important food source for many caiman but also the people of the Beni (Personal observation).

In the Beni there is a large number of floral species with the savannahs being dominated by sedges and grasses such as *Andropogon bicornis*, however there is an estimated 1500 different species of vascular plant present in this north-eastern region. The numbers of trees that are present depend on higher areas of ground where they are not reached by flooding. This then creates a mosaic of trees dotted around the savannah. These create forest "islands" which are vital habitats for the feeding and roosting of the Blue-throated Macaw and other parrot species. Large areas of Cerrado(forest savannah) are present in this region, with many trees being resistant to fire such as *Copernicia alba.* This is a flowing species which provides an important food source many insects and hummingbirds which live in this habitat such as *Eupetomena macroura* a common species found in the Beni.

1.4.2. The Motacu Palm (*Attalea phalerata*)

The Motacu Palm (*Attalea phalerata*)- or simply called motacu, is one of the most dominant species of palm that inhabits the Beni savannah ecosystem. It is a large palm species reaching heights of 20 metres and it is important for the conservation of the critically endangered Blue-throated Macaw (*Ara glaucogularis*) as its fruits provide the majority of the species' diet (Yamashita and Barros, 1997). The Motacu palm is also believed to be of an importance for roost sites in the Llanos de Moxos (Yamashita and Barros, 1997). It provides roost sites for Blue and Yellow Macaws (*Ara ararauna*), Blue-throated Macaws

(*Ara glaucogularis*), and parakeet species such as the Peach-fronted Parakeet (*Eupsittula aurea*) and the White-eyed Parakeet (*Psittacara leucophthalmus*). As is seen in figure 1.1, macaw species tend to clip the palms they roost in, making roosting sites easily identifiable.

The main fruiting period of this palm takes place between November and April, with palms starting to fruit once they reach the ages of 7-10 years old(Moraes et al, 1996). For this reason it is considered to be of high ecological importance (Yamashita and Barros, 1997). Furthermore it has a high economic value in Bolivia as its oils are used to make shampoo, while tonics are made with properties that are claimed to stop achromotrichia (Moraes et al, 1995). They are not only used in the cosmetic industry but they have medicinal uses also. The oil also is taken as a cure for sore joints and pulmonary congestion, while the roots are boiled and eaten to help cure tuberculosis (Moraes et al, 1995). Like with other palm species, Motacu palms are cut down for the palm hearts which is a delicacy in Northern Bolivia.

Figure 1.1: Clipped Motacu palm leaves. This is good evidence of this palms usage by a species of Macaw, possibly as a roost site(Photograph by Christopher Field)

1.4.3. Distribution of the Blue-throated Macaw

The Llanos de Moxos ecosystem is the last remaining habitat that is inhabited by the Blue-throated Macaw; they are restricted to the North-eastern region of Bolivia - as can be seen in figure 1.2 below. It is believed that the species is limited to two separate populations, one larger North of Santa Ana de Yacuma, and a smaller population South of Trinidad of individuals.

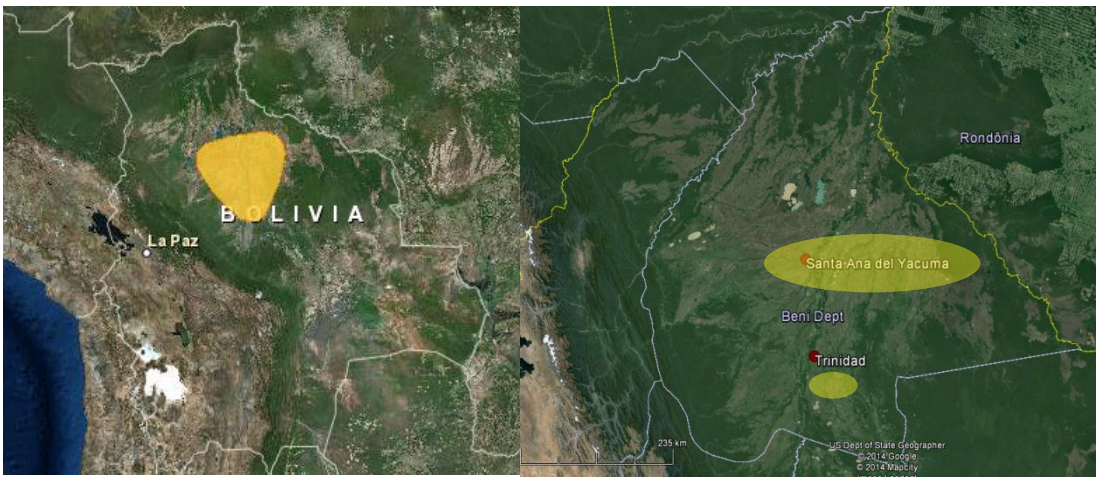

Figure 1.2: Left: map adapted from the IUCN on the Blue-throated Macaw distribution (IUCN, 2014). Right: The two separate populations of the Blue-throated macaw, adapted from google earth

A study in 2012 estimates the northern population to be 160 individuals and the southern population to be 25(Strem and Bouzat, 2012) However it was listed in IUCN redlist in 2014(BirdLife International Species factsheet: *Ara glaucogularis*, 2014) to be an estimated adult population of 73-87 individuals throughout the whole of Bolivia, therefore more information particularly from the northern population is needed for an accurate population estimate.

A study on the breeding success over the period of 2007-2012, 26 Blue-throated Macaws fledged successfully, and a 72% survival rate for new macaw hatchlings, very similar to other macaw species (Berkunsky et al, 2014). The majority of the nest sites were from

hollows of trees such as *Attalea phalerata*. It is believed that successful adults are unlikely to nest the following year, so the success of the young breeding is of upmost importance. It has been found that the Blue-throated macaw is happy to nest in man-made boxes, which could prove crucial to their conservation, and help to increase populations (Berkunsky et al, 2014).Therefore the understanding of this species' habitat usage in the Barba Azul Reserve will be important not only for identifying key areas which require protection, but also determine ideal nest box placement, to help increase breeding success rate.

1.4.4. Distribution of the Blue and Yellow Macaw

The Blue and Yellow Macaw (*Ara ararauna*) inhabits multiple ecosystems with them being observed in subtropical, tropical rainforests, and often near aquatic environments, but are often observed in dry environments (EOL, 2014). They are observed in open land such as savannahs like the Llanos de Moxos plains of North-Eastern Bolivia, and occupy a very large distribution across Latin America- as seen in Figure 1.3 below.

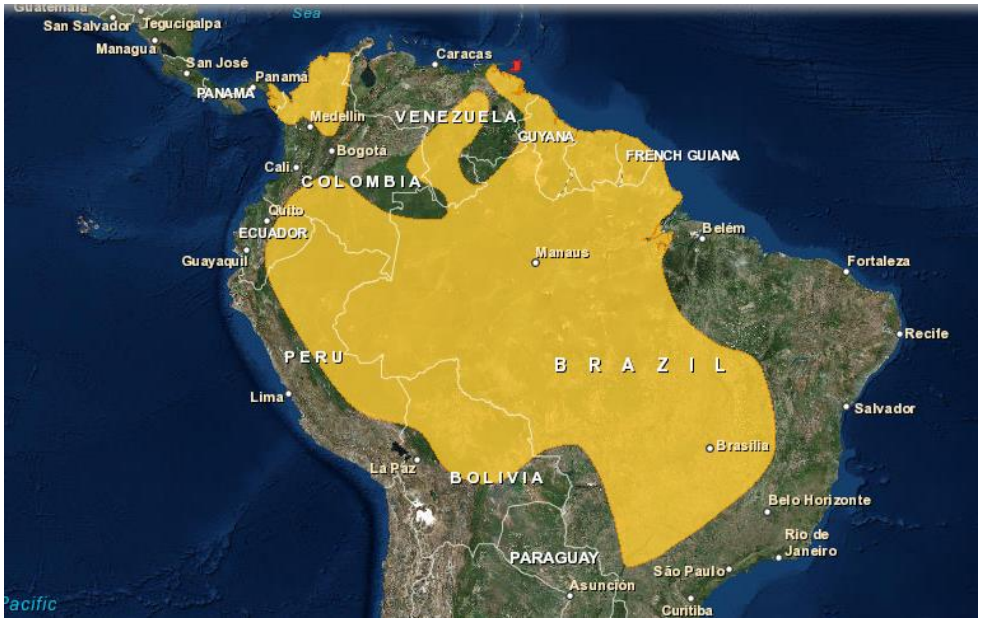

Figure 1.3: Distribution of the Blue and Yellow Macaw across Latin America, adapted from the IUCN.

It is quite obvious that the Blue and Yellow macaw has a much larger distribution and inhabits a multitude of different ecosystems; however, it still succumbs to many of the same threats as the closely related Blue-throated Macaw (BirdLife International, 2012). Like with the Blue-throated Macaw the Blue and Yellow Macaw was heavily traded during the 1980's, with over 50,000 individuals being recorded by the international pet-trade and has been marked on CITES Appendix II (BirdLife International, 2012). Due to the large population distribution it listed as a species of least concern, however it is believed the population is decreasing with an estimated adult population of about 10,000 individuals, a decline of 25% over three generations (BirdLife International, 2012). Due to the lack of quantitative data on this species, it could be at a much higher risk than previously thought, and so like with the Blue-throated Macaw further studies are vital for its conservation.

2. Project Aims:

The project aims – were first to establish the minimum size of the population of the macaw species present in the Barba Azul Reserve. The forest islands present in this reserve, are crucial to the survival of macaw species within the reserve, therefore population studies, will be completed are these forest islands which many use as foraging sites. Flight behaviour was another aspect of the studying of the Blue-throated Macaw as there is no knowledge of the roosting sites of this species. Information on flight behaviour could

allow the distance these macaws are flying before roost to be estimated, and the direction of flight to be established. This could allow for future purchases of ranches where the macaw may be roosting in, further protecting the species. It was also a key part of the project to try and locate the currently unknown roost sites of both the Blue-throated Macaw and that of the Blue and Yellow Macaw within this reserve.

As was mentioned above there is an issue of the use of cattle in the reserve, and this might be having effect on the regeneration of the Motacu palm. This palm offers a crucial food source to the Blue-throated Macaw, but also to many other species which inhabit this ecosystem. Therefore a further aim was to see what degree of regeneration was present in certain forest islands in the reserve. The proportion of Motacu fruiting were calculated to understand foraging availability for macaw species within the reserve.

3. Methods

3.1. Study Site: Reserva Barba Azul, Bolivia

The Study Site was situated in the Barba Azul Reserve, in the Beni department of Bolivia. It is owned by the NGO group Asociacion Armonia, which is a partner with Birdlife International. The reserve, which was a ranch of 8,785 acres area, was originally bought by Armonia in 2008 with the aid of the WLT-US (World Lands Trust United States, 2008) and the American Bird Conservancy group. In 2010 the reserve was extended further to a southern Ranch (Now called Juvenna, which contains the field station) this extended the reserve to a size of 11,555 acres (World Land Trust, Bolivia, 2014)-as can be seen below in figure 3.1.

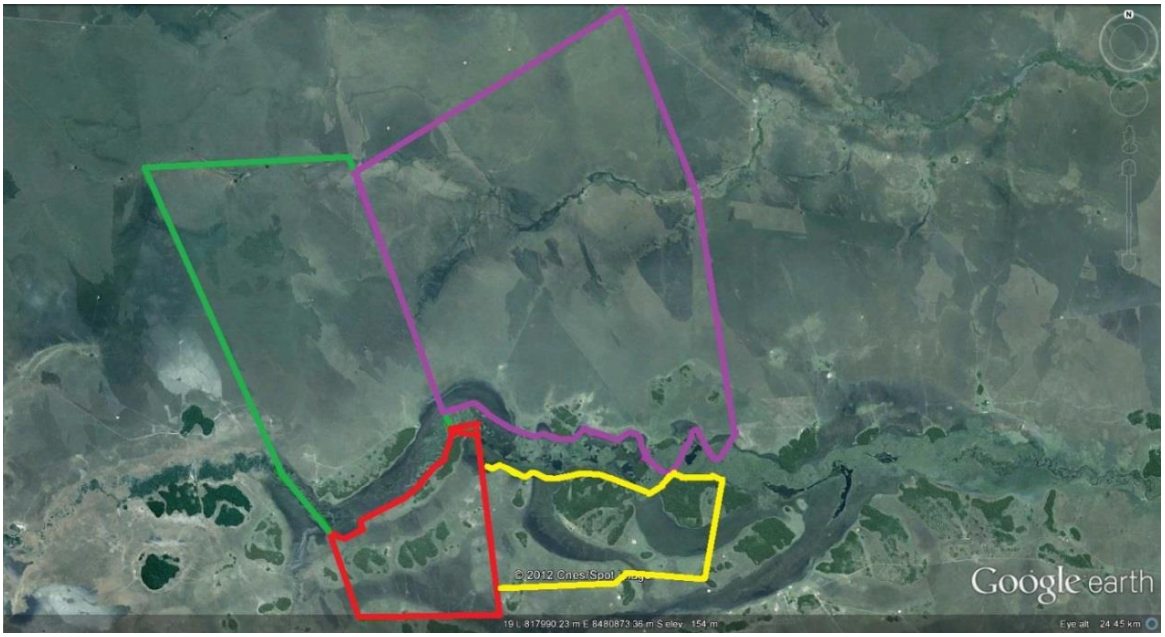

Figure 3.1: Barba Azul Reserve Boundaries; the area in green is the original ranch bought by Associacion Armonia back in 2008, the area depicted in red shows the southern ranch now called Juvenna which now holds the Field station, The area in purple is the newly purchased ranch making the reserve be of 11,034 hectares in size. The area marked in yellow shows an area of interest, as it may hold key habitats for the Blue-throated macaw. (Photograph adapted from the University of Glasgow Bolivia Expedition 2014 Prospectus).

Recently the reserve has extended further; doubling in size with addition of a neighbouring ranch, increasing the size of the reserve to be 11,034 hectares, for the

The older Western part of the reserve is separated by the Rio Omi which separates the Juvenna ranch from the San Lorenzo ranch. The new eastern part of the reserve has a vast plain of savannah dotted with forest islands.

There is great biodiversity in this reserve; the University of Glasgow Bolivia Expedition 2009 found that there were 230 bird species present (University of Glasgow Bolivia Expedition report, 2009). This number is likely to be greater due to the increased size of the reserve.

There is a high degree of large mammals frequently using this reserve with regular sightings of Giant Anteater (*Myrmecophaga tridactyla*), a vulnerable species (Miranda et al, 2014). There have also been camera trap recordings of carnivores such as cats, with a Pampas cat (*Leopardus pajeros)* being caught on camera trap by the University of Glasgow Bolivia 2012 Expedition, and a sighting in the University of Glasgow 2014 expedition. High numbers of Ocelot (*Leopardus pardalis*) have been observed being frequently caught on camera trap (as is shown figure 3.2). The presence of such numbers of carnivorous species is a key indicator for habitat richness

Figure 3.2: Shows an ocelot caught on camera trap by the University of Glasgow Bolivia Expedition 2014.

3.2. Pilot Study: Identifying the Blue-throated Macaw

The Blue-throated macaw holds many similar attributes to that of the sympatric blue and yellow macaw, although there are some clear differences- as can be seen in figure 3.3 below. Facial features are very similar between the two species, however there is more white on the cheeks and face of Blue and yellow macaws. The Blue throated macaw has a large patch of dark blue going from the beak, this extends from the cheeks to the beginning of the chest of the animal, and it is where it gets its name in Spanish of "Barba Azul" or "blue beard". This patch of feathers is larger and much more prominent than that of the Blue and Yellow macaw, which has a smaller and darker patch of feathers that is almost black in colouration. The Primary feathers of the Blue-throated macaw are turquoise pigmentation, compared to a darker blue on the Blue and Yellow Macaw. Another difference in colouration is the lack of the green crown which is present in the Blue and yellow macaw. It was also noted that the Blue-throated macaw is of a smaller size than that of the Blue and yellow Macaw (EOL, 2014)

However, its use as an identification tool in the field is limited (Personal Comment). For this reason the uses of calls were used in

identifying the species whilst conducting fieldwork. The Blue-throated macaw has a much higher pitched call, whereas the Blue and yellow has a call with a much harsher sound. After training the ear the difference between species was quite clear.

Figure 3.3: Shows a comparison of the physical features between the Blue-throated Macaw and the sympatric Blue and Yellow Macaw

A pilot study was completed utilising the skills of identification obtained over the first few days. The study aimed to do a pilot population count survey of the west of the reserve. Fewer point counts were used due to time constraints, than in the real population surveys. Four point counts were used, and this was completed over a two hour period between 16.30 and 18.30. It was found that this is the most likely time to see the macaws leaving to go and roost before dusk (Personal observation).

The methods were as follows; both the Blue-throated and the Blue and yellow macaw were counted, as macaws were seen leaving the forest islands, they were noted whether

they were leaving the island, flying over or arriving at the island. This was accompanied by the direction of the macaws flying by the use of a Silva compass. The numbers of macaws were counted, also if they were travelling in specific family groups. This information can be used to work out the number of breeding macaws are present on this reserve. This is crucial information for the conservation of both species, but more importantly for the critically endangered Blue-throated Macaw, as there is debate whether this species is breeding in the wild.

This pilot study really helped members of the expedition taking part to get a grasp of distinguishing the two main species of macaw present on the reserve (Chestnut-fronted Macaws are present on the reserve; however none were seen at point counts). It also allowed training of using the Silva compass and the practice of population counts, as some students had no experience of this.

Other pilot studies were not performed due to time restraints. It was decided that there was no need for a pilot study on the flight or roosting behaviour of the species as many of the identification skills needed were acquired during the population count pilot study.

3.3. Population Size and Structure

3.3.1. Estimating the Reserve Population Size

Multiple point counts were undertaken on a weekly basis, between 16.30pm and 18.30pm. 3 counts were performed in the west of the reserve, in San Lorenzo, as is seen in figure 3.4 below, all the point count sites (GPS Coordinates can be found in Table 3.1). This figure

shows all the locations students were positioned around "Barba Azul Island" and the directions that the Macaws flew in. Not all of these sites were used in every count due to maximising the detectability of macaws- some locations chose were found not to be favourable locations of pre- roosting macaws. 3 counts were completed in the Eastern part of the reserve as can be seen in figure 3.5(GPS Coordinates can be found in Table 3.2). One count was completed spreading across the reserve to achieve a minimum population using the reserve in the dry season; the locations of this can be seen in figure 3.6(GPS Coordinates can be found in Table 3.3). The methods at each count remained consistent so that the results could be standardised. During these counts the Blue-throated Macaw and the sympatric Blue and yellow Macaw were counted leaving forest islands. During analysis double counts were taken into about, to achieve a minimum population per survey.

Table 3.1: GPS Coordinates of Point Count Locations in Barba Azul West

Number	GPS Name	GPS Coordinate
1	BT43	S 13° 45.743 W 066° 07.242
2	BT42	S 13° 45.673 W 066° 07.279
3	BT44	S 13° 45.438 W 066° 06.960
4	BT77	S 13° 45.743 W 066° 07.242
5	BT75	S 13° 45.743 W 066° 07.242
6	BT5	S 13° 44.758 W 066° 05.834
7	BT46	S 13° 44.998 W 066° 05.844

Figure 3.4: Point Count Locations in Barba Azul West. The red dots signify the count locations. The blue triangles, is the direction of flight macaws were often observed flying

Table 3.2 : GPS Coordinates of Point Count Locations in Barba Azul East

Number	GPS Name	GPS Coordinate
1	BT109	S 13° 44.772 W 066° 04.131
2	BT115	S 13° 44.430 W 066° 04.125
3	BT114	S 13° 44.432 W 066° 03.847
4	BT113	S 13° 44.455 W 066° 03.560
5	BT176	S 13° 45.743 W 066° 07.242
6	BT177	S 13° 44.898 W 066° 03.681

7	BT167	S 13° 45.044 W 066° 02.708
8	BT178	S 13° 44.981 W 066° 02.443
9	BT151	S 13° 44.722 W 066° 02.189
10	BT116	S 13° 44.237 W 066° 02.840

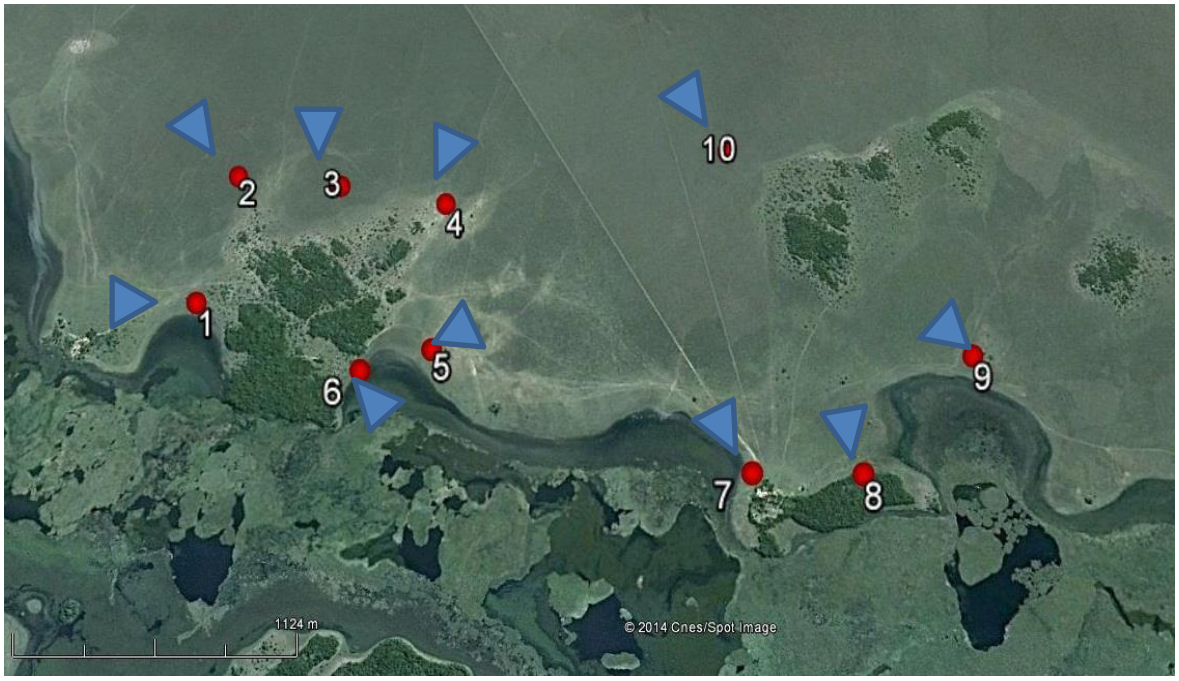

Figure 3.5: Point Count Locations in Barba Azul East. The red dots signify the count locations. The blue triangles, is the direction of flight macaws were often observed flying

Table 3.3: GPS Coordinates of Point Count Locations on the whole reserve count

Number	GPS Name	GPS Coordinate
1	BT42	S 13° 45.743 W 066° 07.242
2	BT5	S 13° 45.673 W 066° 07.279
3	BT6	S 13° 44.898 W 066° 05.675
4	BT115	S 13° 44.430 W 066° 04.125
5	BT109	S 13° 44.772 W 066° 04.131
6	BT167	S 13° 45.044 W 066° 02.708
7	BT178	S 13° 44.981 W 066° 02.443

8	BT151	S 13° 44.722 W 066° 02.189

.

Figure 3.6: Point Count Locations on the entire reserve count. The red dots signify the count locations. The blue triangles, is the direction of flight macaws were often observed flying

3.3.2. Population Structure of the Reserve Macaw Species

During reserve population counts, information was also collected on the family sizes of the Blue-throated macaw and Blue-and yellow macaw species. Groups of Blue-throated Macaws and Blue and Yellow Macaws would be identified; they were categorized into groups, of those flying in close proximity to each other. Groups of sizes between 1 and 6 were counted. Groups observed larger than 6 in number were not counted as it was

assumed that groups of them sizes may be multiple smaller groups flying in close proximity, and it is highly unlikely of them being observed..

3.4. Flight Behaviour of the Blue-throated Macaw

Studies were conducted to understand flight behaviour; Blue-throated Macaws were recorded flying over a measured 300 metre distance. Radios were used and Blue-throated macaws were timed crossing this distance. Two students were required to identify the macaws leaving the main forest island and would radio with a number of individuals. The direction they were flying in was also noted by the use of a Silva compass. Another student would be present 300 metres away and time them crossing this distance. This allowed for their flight speed to be calculated- figure 3.7 shows the locations of were flight behaviour studies were completed on the reserve (GPS Coordinates can be found in Table 3.4).

Table 3.4: GPS Coordinates of Identifier, and Timer' location in flight behaviour study

Number	Occupation	GPS Coordinate
1	Identifier	S 13° 44.791 W 066° 05.866
2	Timer	S 13° 44.643 W 066° 05.797

Figure 3.7: Flight behaviour surveys had two students at location 1 to identify the species, and another observer at location 2 to time the species over a 300 metre distance

3.5. Roosting Behaviour of the Blue-throated Macaw

The communal roost sites of the reserve population of the species were unknown, groups of researchers therefore travelled to the small forest islands of the north, the locations of these forest islands can be seen in figure 3.8(GPS Coordinates can be seen in Table 3.5). Separate trips were made to collect the information required. This was completed by horseback on two of the trips, due to the height of the water and distance. Another trip was made to the central North by foot. At these forest islands Blue-throated Macaws and Blue and yellow Macaws were recorded arriving at these islands. These counts were

completed with the same methods to that of the population counts. They were categorized into arriving, leaving, and flying over, also the direction that they were flying was noted down. Family groups were also noted to provide more data on the breeding success of these macaws. One count was completed at each island due to time constraints.

Table 3.5: GPS Coordinates of the northern Forest Islands studied during the project

Map Number	Island	GPS Coordinate
1	2A	S 13° 41.621 W 066° 08.242
2	1A	S 13° 41.589 W 066° 08.137
3	3A	S 13° 41.427 W 066° 07.834
4	4A	S 13° 41.322 W 066° 06.307
5	5A	S 13° 41.357 W 066° 06.137
6	6A	S 13° 41.182 W 066° 06.164
7	3B	S 13° 42.944 W 066° 05.796
8	4B	S 13° 42.310 W 066° 05.204
9	5B	S 13° 42.169 W 066° 04.162
10	6B	S 13° 41.955 W 066° 03.927
11	7B	S 13° 41.907 W 066° 03.832
12	8B	S 13° 41.913 W 066° 03.666
13	9B	S 13° 41.804 W 066° 03.575
14	10B	S 13° 41.637 W 066° 03.284
15	11B	S 13° 41.379 W 066° 03.534
16	12B	S 13° 41.916 W 066° 02.543
17	13B	S 13° 41.802W 066° 02.121
18	14B	S 13° 41.820 W 066° 02.102
19	15B	S 13° 41.041 W 066° 02.206

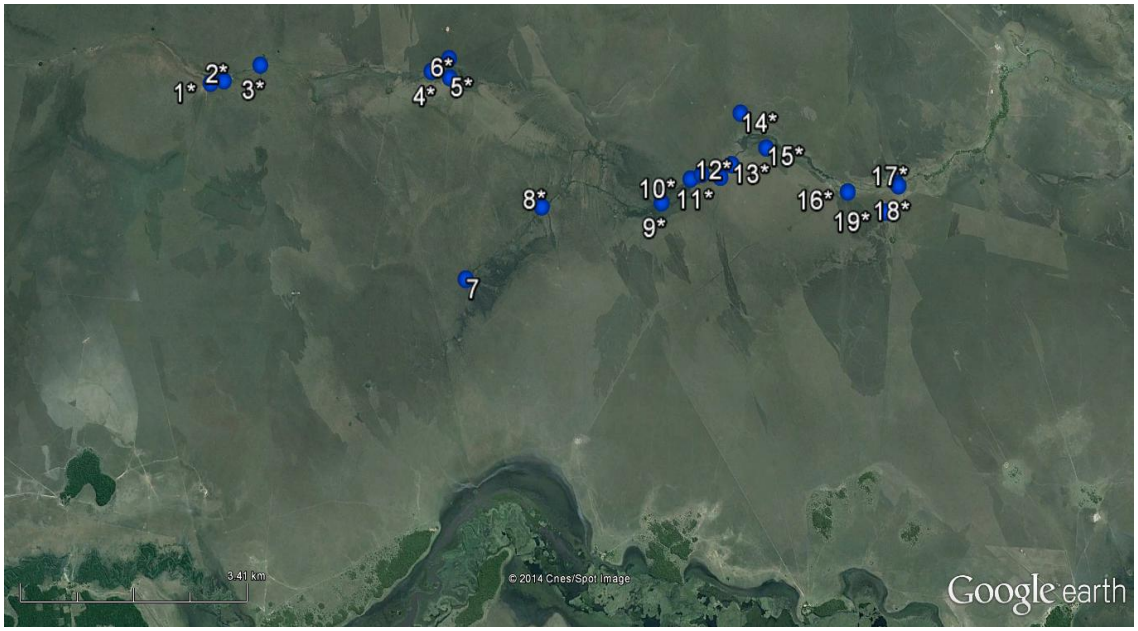

Figure 3.8: Forest Islands Studied for Macaw Roosting(Those not marked with "" were not studied due to time constraints*

3.6. Habitat Usage of the Blue-throated Macaw

3.6.1 Motacu Palm Transects

To get an understanding of the Motacu palm availability, transects were undertaken through the forest islands. Here two students would walk through areas of Motacu palm forest. One student would count the number of trees, a number adding up to 100 Motacu palms, or 50 depending on the size of the forest island in question. On these walkthroughs the student would count the number of palms, two metres to the left and right of him/her. The number of palms that had clear fruiting Motacu would be counted and the other student would note down whether it is a feeding tree.

Feeding trees potentially available to macaws were identified based on having at least six freshly eaten Motacu, consumed by any species- figure 3.9 shows a Blue-throated Macaw

consuming a Motacu nut; different species show different behaviours in consuming Motacu. Indicator marks used to distinguish which species had been eating the Motacu can be seen in figure 3.10. The start point, end point and the feeding trees locations were marked by GPS points, as well as the whether there was a change of direction in the walkthrough, due to the Motacu palm forest ending. By undertaking this survey a proportion of fruiting/feeding Motacu to non-fruiting was worked out, providing information on which forest islands provide potential feeding resources for the species.

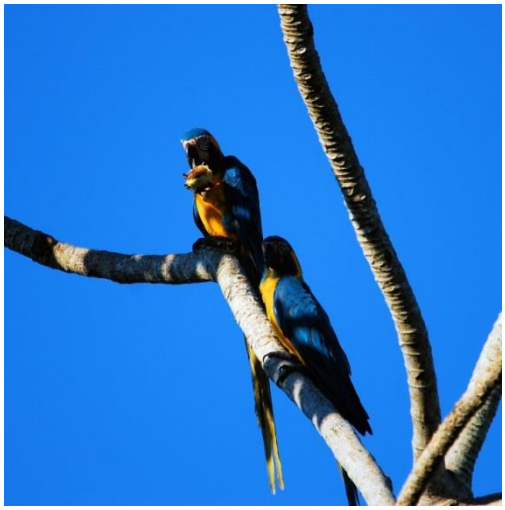

Figure 3.9: Blue-throated Macaw Consuming a Motacu Nut

Figure 3.10: Comparison of striations in mesocarp by different macaw species. The blue throated macaw can be identified by its horizontal striations it leaves in the mesocarp due to the way it hold the motacu nut in its feet (seen on the left in the photograph). The sympatric blue and yellow macaw show vertical striations striation (seen in the middle). Golden Collared Macaw leave no marks (seen on the far right).Monkeys leave clear teeth marks in the mesocarp so is easily identifiable(Not seen in the photograph).(Photograph taken by Joanne Kingsbury)

3.6.2. Motacu Tree Measurements and Regeneration Plots

At each feeding tree which is found on the Motacu palm surveys tree measurements were taken. The number of palms to be measured is the 9 closest Motacu and the actual feeding tree. By the use of measuring tape, the diameter of the palms could be measured. A clinometer was used combined with a distance measurement to get the height of the palms. Additionally a 10x2 metre measurement was taken of the height of any regenerating Motacu surrounding the feeding tree. These had 3 categories - below knee height, waist height, and above head height. Other locations were also chosen in forest islands in sites of significant regeneration, the same methods were used as at feeding trees to achieve results. The information from the regeneration plots was collected to help the understanding of regeneration level in different forest islands, therefore understanding the future of this palm.

3.6.3. Assessing Characteristics of Forest Islands

Visits to potential roosting forest islands were made during trips up to the north of the reserve. Here characteristics and observations were noted. The point of this exercise was to try find evidence of macaw usage of these islands, particularly that of the blue-throated macaw. With the aim of trying to understand the reasons for island usage or not. Characteristics that were investigated was whether there is a presence of Motacu, whether they are being consumed, if there is evidence of cattle, evidence of wolf apple, and evidence of macaw usage(Feathers present, palm leaves clipped.).

After this was completed, GPS coordinates were taken of the islands, and any

Blue-throated macaws seen in the island were noted down

3.10. Analysis

The results obtained were analysed with the use of the program RStudio (Version 0.98.1087). Utilising this program allowed statistical models to be fitted to the data obtained, and bar plots to be obtained.

4. Results

4.1. Macaw Population Size and Structure

4.1.1. Estimating the Reserve Population Size

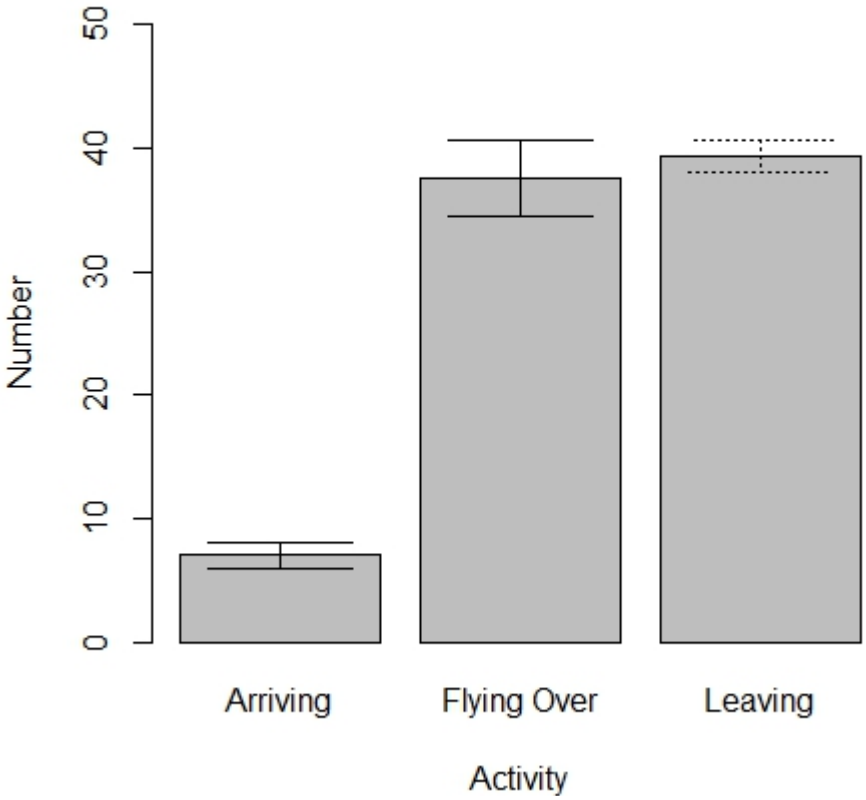

Figure 4.1: The Sum of Blue-throated Macaws observed, Arriving, Flying Over or Leaving Forest Islands on Different Survey Dates

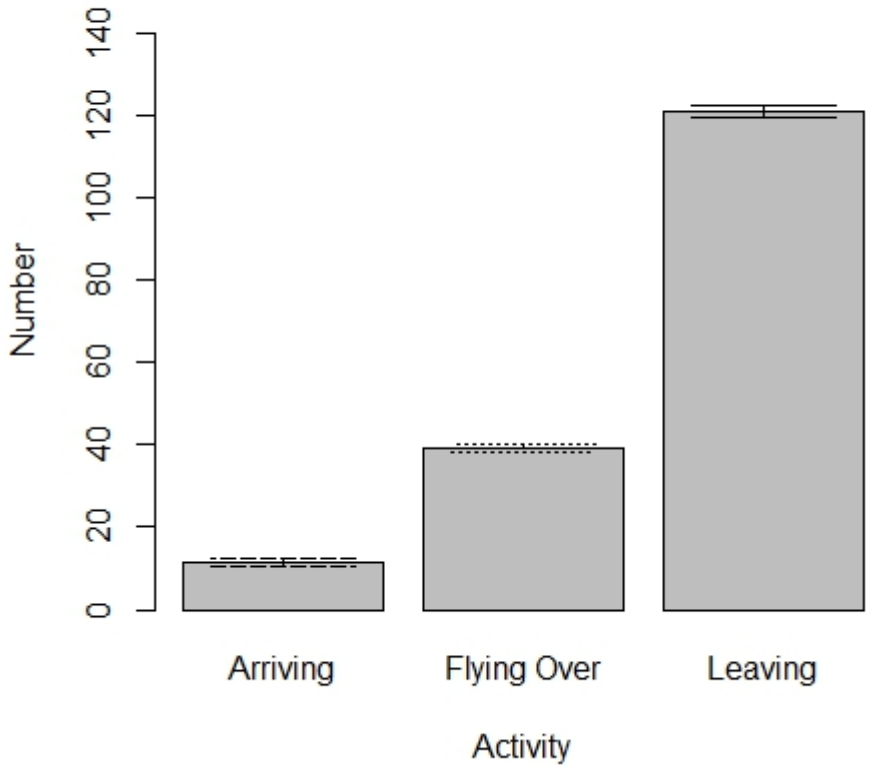

Figure 4.2: The Sum of Blue and Yellow Macaws observed Arriving, Flying Over or Leaving Forest Islands on Different Survey Dates

Table 4.1: Survey Dates and Area of Reserve Taken

Survey Number/Date	Area of Reserve
1: 26/07/14	West
2: 02/08/14	West
3: 09/08/14	West
4: 16/08/14	East
5: 23/08/14	East
6: 30/08/14	East
7: 02/09/14	Whole Reserve

It is recorded that the mean number of Blue-throated Macaws arriving per survey is 7.0(95% CI: 5.98-8.02).For Flying Over there is a recorded mean of 37.6(95% CI: 34.5- 40.6), and similar numbers were recorded for Leaving, with a mean of 39.9(95% CI: 38.2-40.6)-

this information can be visualised in the bar plot in Figure 4.1. In terms of the Blue and Yellow Macaw, the mean number arriving per survey of 11.3(95% CI: 10.3-12.2), 39.1 (95% CI: 38.2-40.1), for Flying Over, and a much higher value for Leaving of 121.0(95% CI: 119.7-122.3) - visualised in Figure 4.2. The locations of the surveys within the Barba Azul Reserve can be seen in Table 4.1.

Table 4.2: Total Numbers Detected of Blue-throated Macaw, and Blue and Yellow Macaw being observed heading to roost sites (With the exclusion of double counts)

Survey Date	Blue-throated Macaw	Blue and Yellow Macaw
26.07.14	82	307
02.08.14	64	150
09.08.14	85	210
16.08.14	30	490
23.08.14	53	454
30.08.14	111	199
02.09.14	83	436
Mean	72.5	320.8

Double counts have been taken account and a minimum population estimate for both species can be seen. Numbers of the Blue-throated Macaw have shown numbers varying from 30 individuals to 111 individuals seen. This makes the minimum reserve population to be an estimated 111 individuals. In terms of the Blue and Yellow Macaw, numbers ranged from 150 to 490. So an estimated minimum population using the reserve is 490. It was also calculated that the mean number of Blue-throated Macaws across all the surveys is 72.5, whereas it is 320.8 for the blue and yellow macaws. This implies that there is an estimated 4.5 times more Blue and Yellow Macaws using the reserve than Blue-throated Macaws.

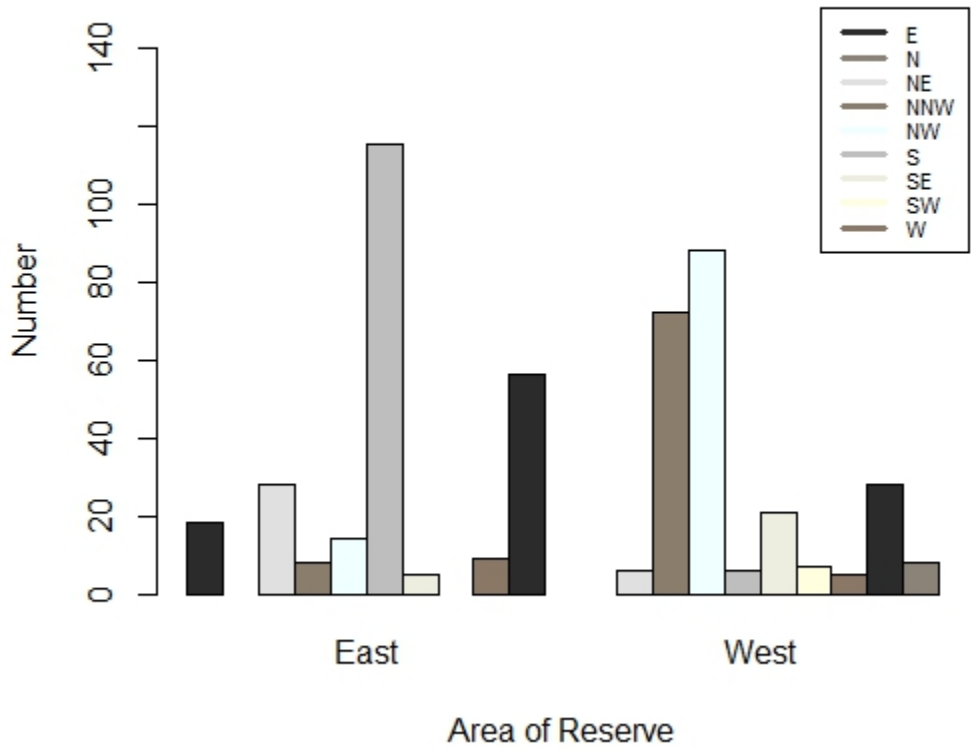

Figure 4.2: Flight Direction observed of Blue-throated Macaws on Different Areas of the Barba Azul Reserve and on the Entire Reserve count

Table 4.3: Summary of a GLM looking at whether there is a significant difference in the flight directions of the Blue-throated Macaw. Here it shows that it is statistically significant

Coefficients	Estimate	Std. Error	t-value	p-value
Intercept	3.000e+00	1.365e+01	0.22	0.828
N	1.229e+01	1.547e+01	0.79	0.435
NE	2.340e+01	1.615e+01	1.45	0.160
NNW	7.000e+00	1.930e+01	0.36	0.720
NW	4.100e+01	1.671e+01	2.45	0.022
S	-9.333e+00	1.671e+01	0.00	1.000
SE	-5.000e-01	1.930e+01	-0.03	0.980
SW	9.333e+00	1.762e+01	0.53	0.601
W	1.550e+01	1.671e+01	0.92	0.363

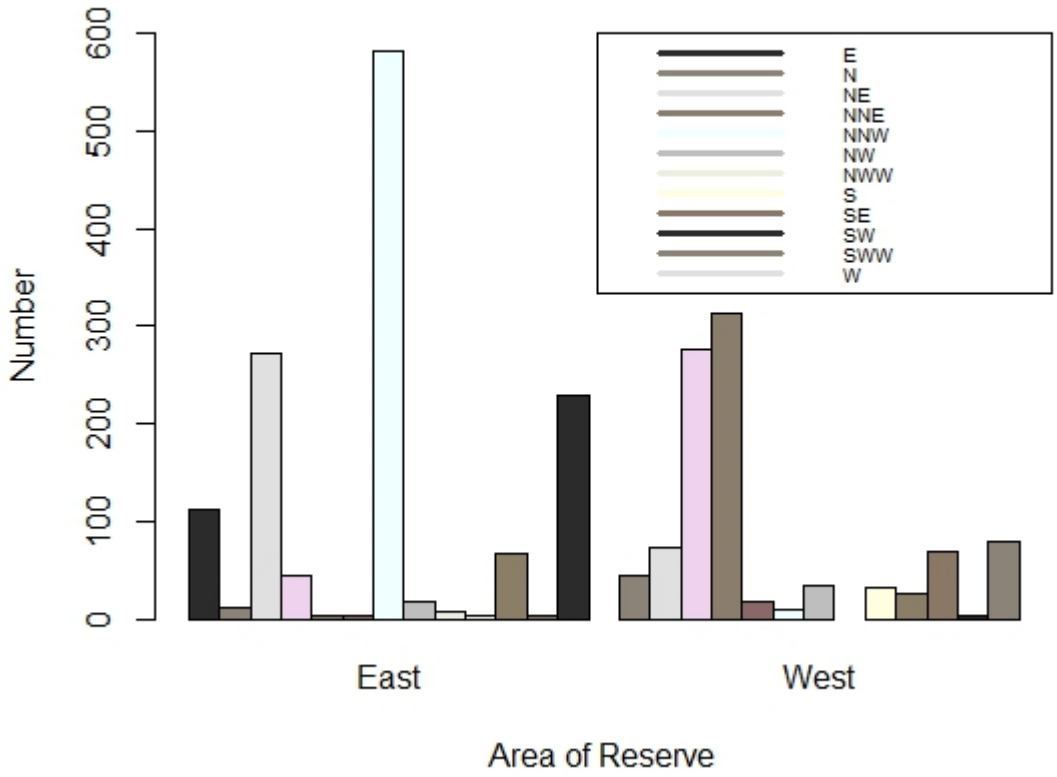

Figure 4.4: Flight Direction observed of Blue and Yellow Macaws on Different Areas of the Barba Azul Reserve and on the Entire Reserve count

Table 4.4: Summary of a GLM looking at whether there is a significant difference in the flight directions of the Blue and Yellow Macaw. Here it shows that no significance in the directions taken by the Blue and Yellow Macaw.

Coefficients	Estimate	Std. Error	t-value	p-value
Intercept	20.667	20.423	1.01	0.317
N	85.619	27.832	3.08	0.004
NE	39.476	27.832	1.42	0.163
NNE	-13.667	35.374	-0.39	0.701
NNW	-14.167	40.847	-0.35	0.730
NW	75.762	27.832	2.72	0.009
NWW	-3.667	54.035	-0.07	0.946
S	-9.867	30.293	-0.33	0.746
SE	-10.917	32.292	-0.34	0.737
SW	4.905	27.832	0.18	0.861
SWW	-16.667	40.847	-0.41	0.685
W	39.476	27.832	1.42	0.163

Blue-throated Macaw was observed in the all counts with the majority displaying a northerly flight direction. In the new Eastern section of the reserve, high numbers of this species were recorded flying in a North Westerly direction, with a total of 115 individuals being observed flying that direction. 56 individuals were observed flying west, another large proportion of this species in that section of the reserve. In the older western section of the reserve, the flight directions observed were mostly northerly with 88 going North East, 72 North, and 21 North. 28 were seen flying South West, numbers which were not observed in the Eastern section of the reserve. It has been found that it is statistically significant that there is an increased number flying North-West (GLM: NW, $t_{1,32}$=2.45, p=0.02).This information is visualised in figure 4.3 above (All other GLM outputs can be seen in table 4.3).

In comparison, the Blue and Yellow Macaw displayed a much more varied degree of flight directions. In the Eastern section of the reserve, direction was very similar to the Blue-throated Macaw with 273 flying North, 581 North West, and 228 West. However in the West, high numbers were recorded of the species flying Southerly, with 33 going South, 26 South East, and 68 South West. Like with the East high numbers were still recorded going northerly with 276 flying North and 314 going North East. It was found that it is statistically significant that more macaws fly north (GLM: N,$t_{1,57}$=3.08, p=0.004) and north westerly (GLM: NW, $t_{1,57}$=2.72, p=0.009). This information is visualised in figure 4.4 above (All other GLM outputs can be seen in table 4.4).

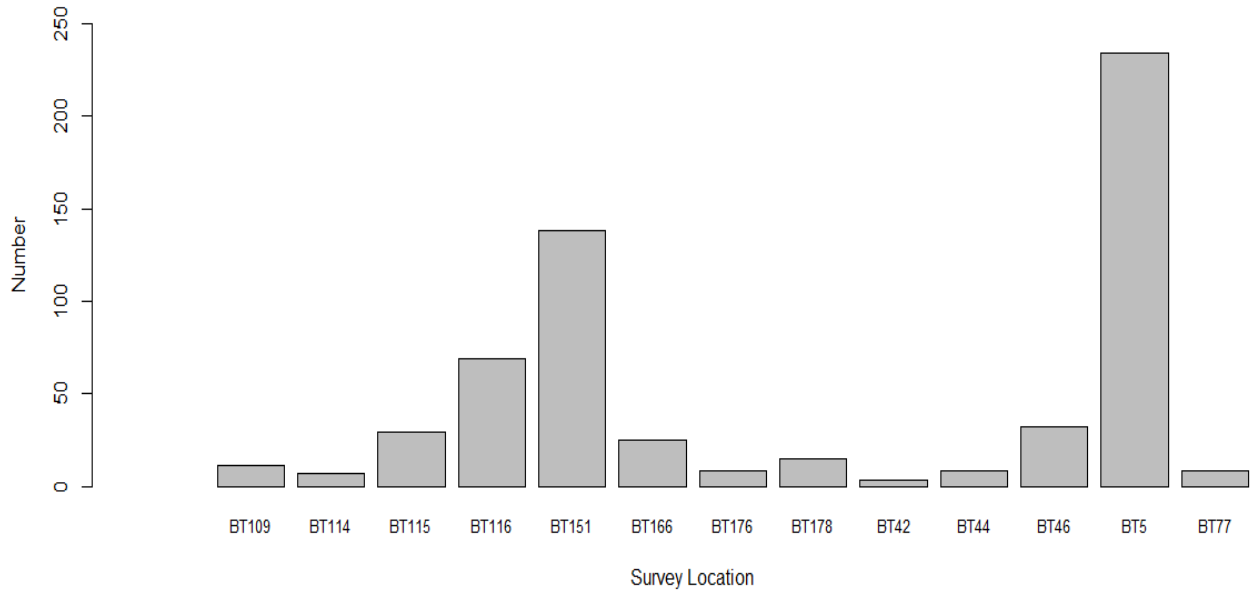

Figure 4.5: Total Numbers of Blue-throated Macaws seen at different survey locations of the Barba Azul Reserve

Table 4.5: GLM investigating whether there is a reason for the numbers of Blue-throated Macaws observed at different locations. Here it is found that it is statistically significant where these macaws are observed

Coefficients	Estimate	Std Error	t- value	p- value
(Intercept)	3.6667	6.1793	0.59	0.563
BT114	3.3333	12.3586	0.27	0.791
BT115	10.8333	9.7703	1.11	0.287
BT116	30.8333	9.7703	3.16	0.008
BT151	42.3333	8.7389	4.84	P<0.001
BT166	8.8333	9.7703	0.90	0.383
BT176	0.3333	9.7703	0.03	0.973
BT178	1.3333	8.7389	0.15	0.881
BT42	-0.6667	12.3586	-0.05	0.958
BT44	4.3333	12.3586	0.35	0.731
BT46	28.3333	12.3586	2.29	0.039
BT5	54.8333	8.1744	6.71	P<0.001
BT77	4.3333	12.3586	0.35	0.731

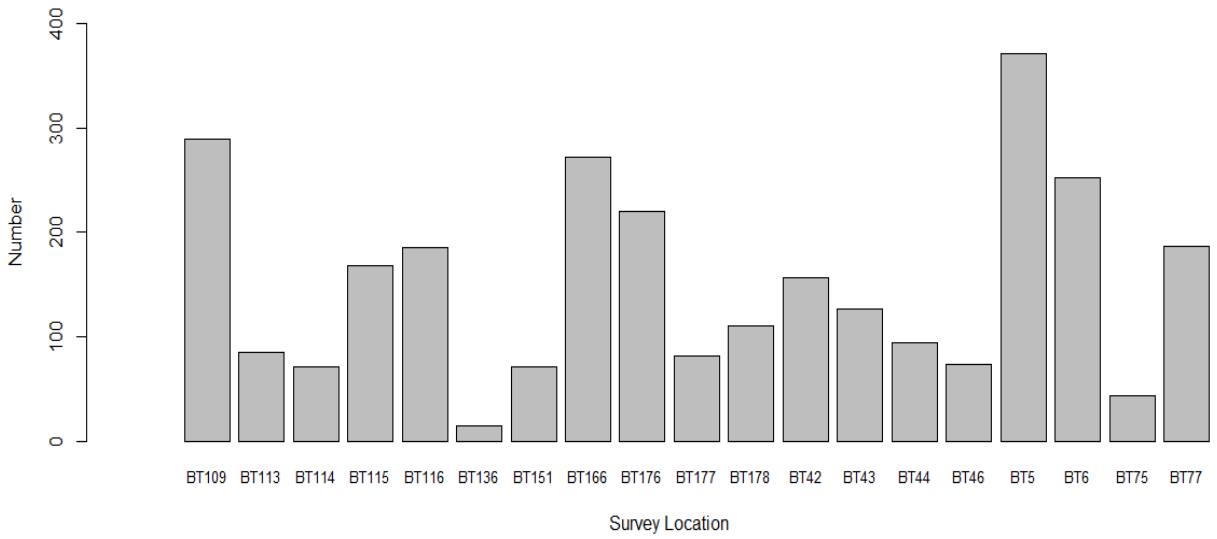

Figure 4.6: Numbers of Blue and Yellow Macaws seen at different areas of the Barba Azul Reserve on different survey dates

Table 4.6: GLM investigating whether there is a reason for the numbers of Blue and Yellow Macaws observed at different locations. Here it is found that it is statistically significant in certain locations where these macaws are observed.

Coefficients	Estimate	Std Error	t- value	p- value
(Intercept)	72.250	17.832	4.05	P<0.001
BT113	-29.750	30.886	-0.93	0.343
BT114	-36.750	30.886	-1.19	0.243
BT115	-16.250	27.239	-0.60	0.555
BT116	-10.250	27.239	-0.38	0.709
BT136	-57.250	39.874	-1.44	0.161
BT151	-48.583	27.239	-1.78	0.08
BT166	-4.250	27.219	-0.17	0.867
BT176	1.083	27.239	0.04	0.969
BT177	9.750	39.874	0.25	0.808
BT178	-44.750	25.219	-1.77	0.086
BT42	-19.917	27.239	-0.73	0.470
BT43	-40.500	25.219	-1.61	0.118
BT44	-25.250	30.886	-0.82	0.420
BT46	-35.250	30.886	-1.14	0.262
BT5	20.500	25.219	0.81	0.422
BT6	179.750	39.874	4.51	P<0.001
BT75	-50.750	30.886	-1.64	0.110
BT77	2.750	30.886	0.09	0.930

Blue-throated Macaw displayed a very localised activity during the pre-roosting population surveys, with certain areas observing the majority of macaws in the surveys. The highest numbers were observed at location BT5 where a total of 234 individuals were observed, following this high numbers were observed at BT151 (n=168) and at BT116 (n=69). It was found that it is statistically significant that higher numbers are seen at BT116(GLM: BT116, $t_{1,25}$=3.16, p=0.008), at BT151(GLM: BT151, $t_{1,25}$, p=<0.001), at BT46 (GLM: BT46, $t_{1,25}$=2.29, p=0.03), and at BT5(GLM: BT5, $t_{1,25}$=6.71, p=0.001). This information is visualised on the bar plot in figure 4.5 above (All other GLM outputs can be seen in table 4.5). The Blue and Yellow Macaw displayed high numbers in a multitude of locations across the population surveys. Similarly with the Blue-throated Macaw, this species had high numbers observed at BT, with 371 individuals being observed. However, other locations also displayed high numbers for this species with BT109 (n=289), BT166 (n=272), BT176 (n=220) and BT6 (n=252) all recording more than 200 individuals of this species. It has been found that it is statistically significant that higher numbers are seen at BT6 (GLM: BT116, $t_{1,49}$=4.51, p=<0.001)This information is visualised on the bar plot in figure 4.6 (All other GLM outputs can be seen in table 4.6).

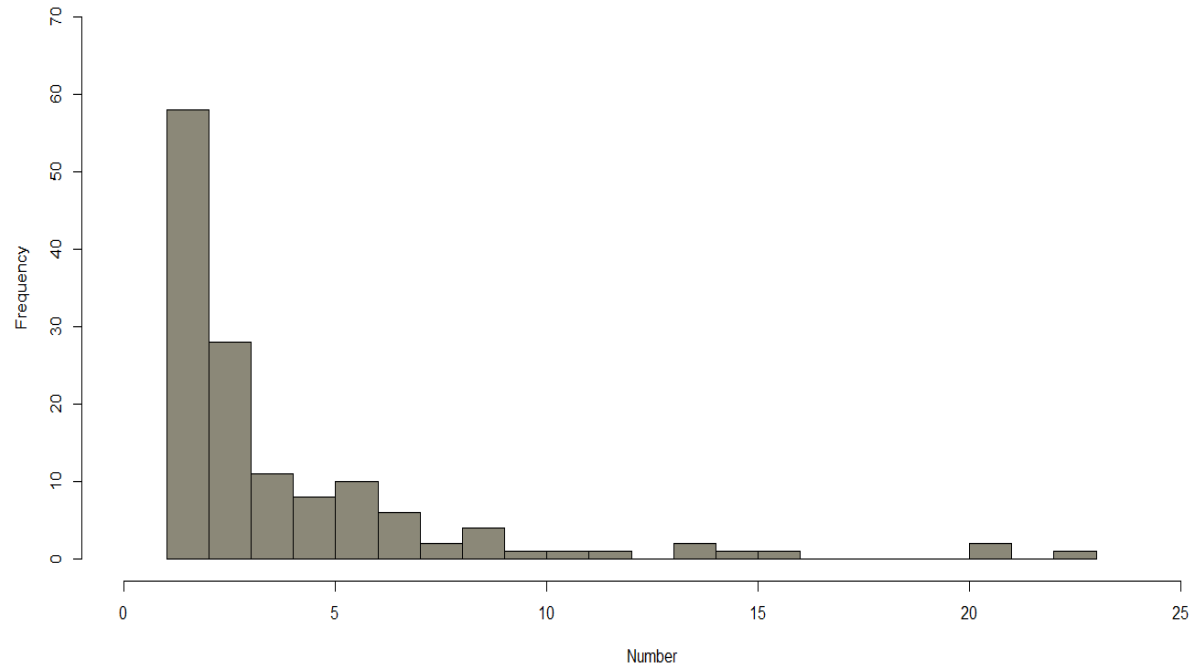

Figure 4.7: Shows the frequency of Blue-throated Macaw group sizes across all population counts

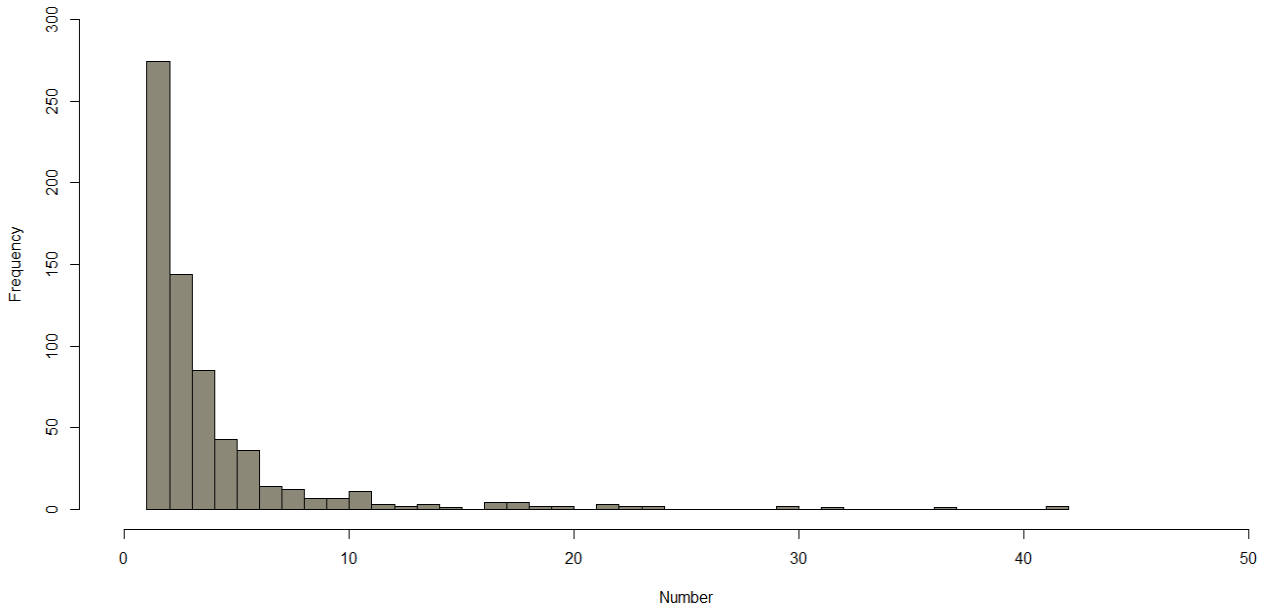

Figure 4.8: Shows the frequency of Blue-throated Macaw group sizes across all population counts

Many macaws of both species are found to leave in smaller group sizes, with the majority group size of 1-3. Some group sizes were recorded at higher than 10 in number were more infrequent in both species. However it is noted that the Blue and Yellow macaw shows a higher frequency of these larger group sizes than the Blue-throated macaw does. This information is displayed in the figure 4.7 for the Blue-throated Macaw and figure 4.8 for the Blue and Yellow Macaw.

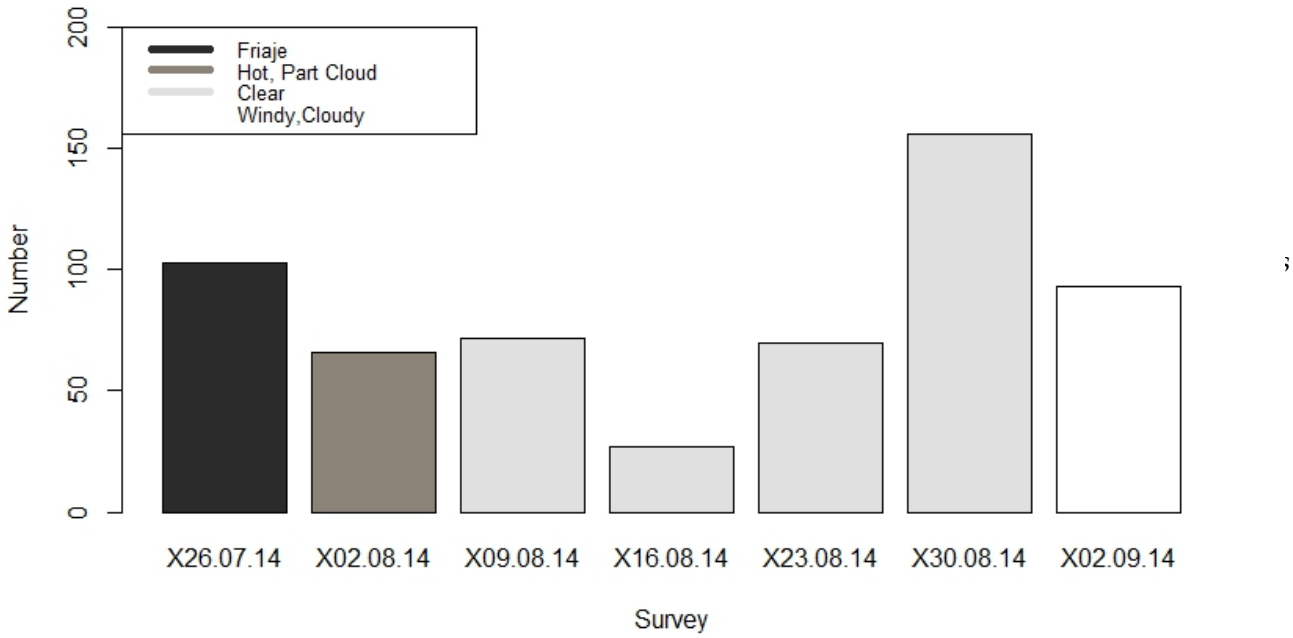

Figure 4.9: Bar plot for the Number of Blue-throated Macaws observed in different weather conditions

Table 4.9: A summary of a GLM looking at whether the number of Blue-throated Macaws differs due to different weather conditions. The low statistical significance shows that this species is not affected by different weather conditions

Coefficients:	Estimate	Std. Error	t- value	p-value
(Intercept)	47.774	10.400	4.594	P<0.001
Weather Friaje	5.892	21.925	0.269	0.789
Weather Hot, Part Cloud	-26.474	21.058	-1.257	0.214
Weather Windy, Cloudy	19.601	22.963	0.854	0.397

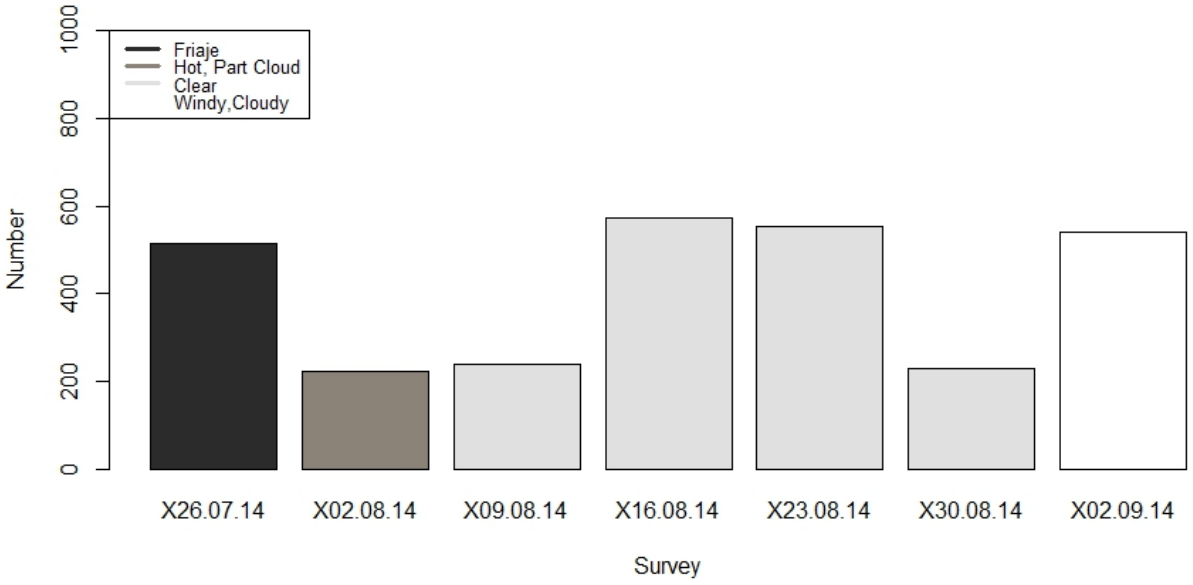

Figure 4.10: Bar plot for the Number of Blue and Yellow Macaws observed in different weather conditions

Table 4.10: A summary of a GLM looking at whether the number of Blue and Yellow Macaws differs due to different weather conditions. The low statistical significance shows that this species is not affected by different weather conditions

Coefficients:	Estimate	Std. Error	t- value	p-value
(Intercept)	47.774	10.400	4.594	P<0.001
Weather Friaje	5.892	21.925	0.269	0.789
Weather Hot, Part Cloud	-26.474	21.058	-1.257	0.214
Weather Windy, Cloudy	19.601	22.963	0.854	0.397

In the Figure 4.9 above, it is observed the numbers of Blue-throated Macaws seen on survey dates in different weather conditions; it was found that there is no statistical significance to an increase or decrease in numbers in different weather conditions for both

macaw species - as seen in tables4.9 and 4.10. In figure 4.10, this can be observed for the Blue and Yellow Macaw. It can be seen for that both species show very similar characteristics in the different weather conditions. There were many more macaws seen on the clear weather condition surveys. This more than doubles per survey any other numbers found. It was found that for both species that during very hot conditions, fewer macaws were seen , and similar numbers are visualised in cooler conditions such as Friaje and Windy, cloudy environments.

4.1.2. Population Structure of the Blue-Throated Macaw and the Blue and Yellow Macaw

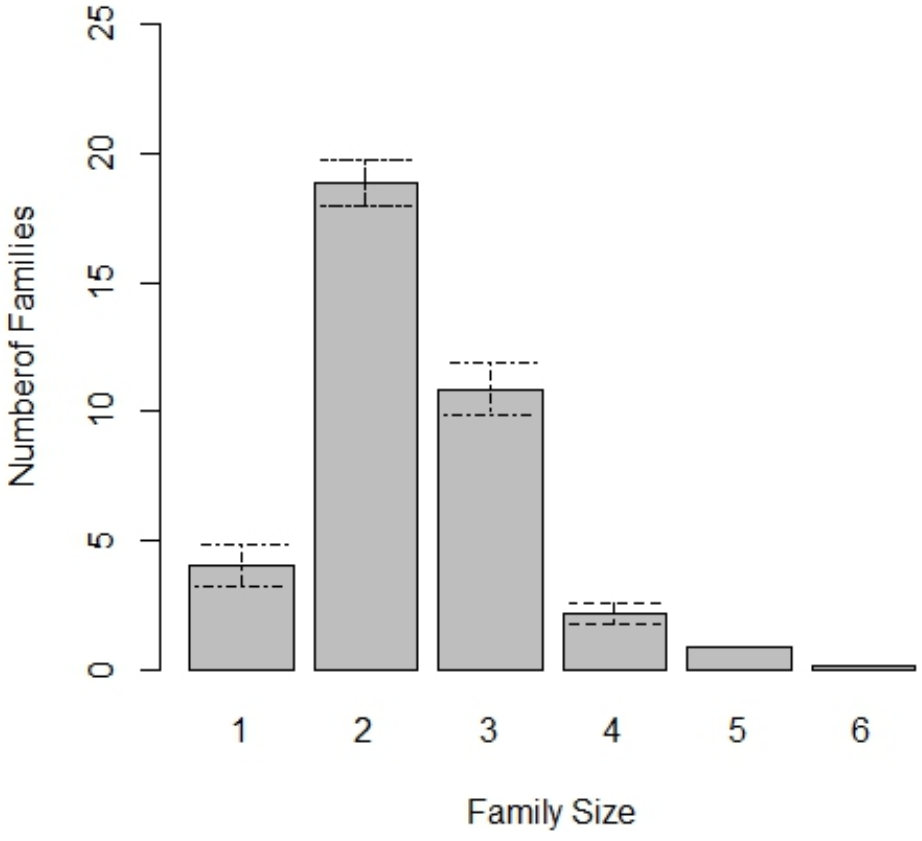

Figure 4.11: Bar plot of the Number of Families and family size seen on survey counts of the Blue-throated Macaw

Table 4.11: Displays the Mean number of families and young observed on survey dates for the Blue-throated Macaw

Survey Date	No. of Non-breeding Families	No. of Breeding Families	Number of Young	Number of Adults
26/07/14	35	13	19	61
02/08/14	15	8	12	45
09/08/14	24	19	25	82
16/08/14	5	4	4	13
23/08/14	20	9	9	58
30/08/14	47	34	40	116
02/09/14	14	11	19	36
Mean:	22.9	15.7	18.3	58.7
Mean Proportion:	59.4%	40.6%	23.8%	76.2%
CI 95%	48.7-74.9	29.0-47.4	7.3-29.3	28.0-89.4

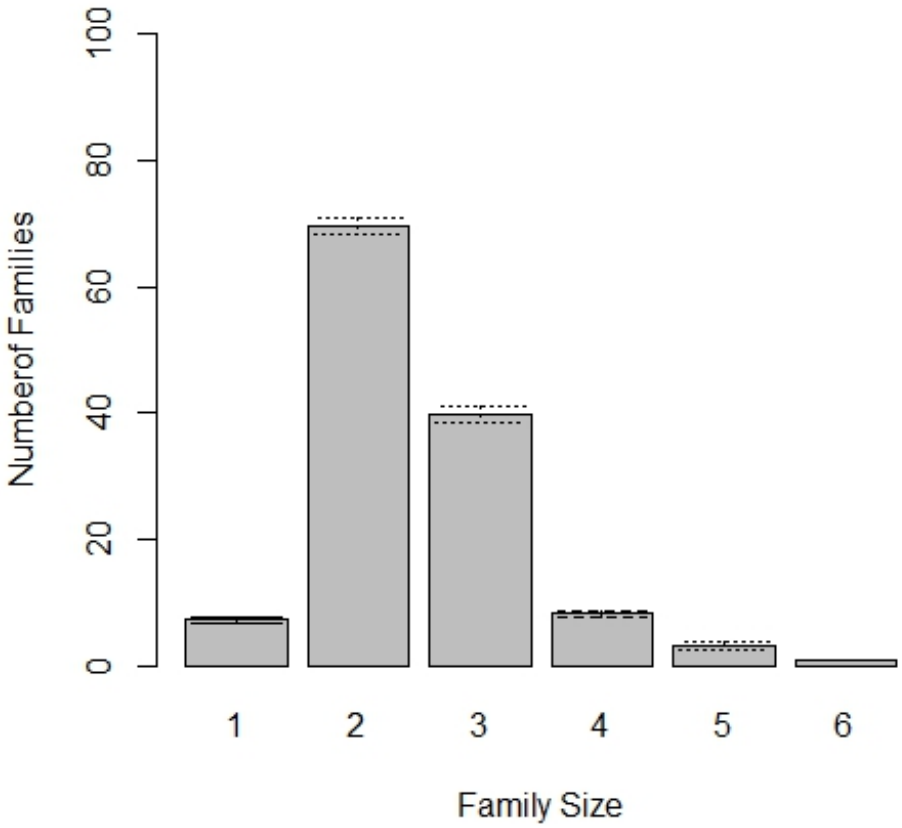

Figure 4.12: Bar plot of the Number of Families and family size seen on survey counts of the Blue and Yellow Macaw

Table 4.12: Displays the Mean number of families and young observed on survey dates for the Blue and Yellow Macaw

Survey Date	No. of Non-Breeding Families	No. of Families Breeding Families	Number of Young	Number of Adults
26/07/14	44	23	33	129
02/08/14	47	34	59	166
09/08/14	105	43	55	286
16/08/14	101	82	102	355
23/08/14	104	88	116	379
30/08/14	56	32	36	172
02/09/14	81	60	77	270
Mean:	76.9	51.7	77.7	251.0
Mean Proportion:	59.8%	40.2%	23.6%	76.4%
Confidence Level (95%)	25.4	23.6	29.3	90.3
CI 95%	51.5-102.3	28.1-75.3	39.0-97.6	160.7-341.3

It is found that there is a high number of paired birds but also those of a family size of 3 in the Blue-throated Macaw population(as seen in figure 4.11), and it was observed throughout the majority of the survey dates. There were considerably fewer numbers of those of family size 1, 5 and 6. Table 4.11 displays the numbers of non-breeding families to breeding families; it is found that there is a mean proportion of 40.6% of the population that is breeding with 23.8% of the population being fledged young. It is found, that in a 95% confidence interval that the mean number of young per survey is likely to be between 29.3 and 7. It is found that similarly to the Blue-throated Macaw, the Blue and Yellow Macaw family sizes were either 2 or 3 individuals (as is seen in figure 4.12). Table 4.12 displays the proportions of breeding and non-breeding families; it is found that there is a

mean of 40.2% of the population is breeding families. It i--s also found that there is a mean of 23.6% of the population is fledged young. Through a 95% confidence interval, the mean number of young per survey is likely to be between 97.6 and 39.0.

4.2. Blue-throated Macaw Flight Behaviour

Table 4.13: Displays the Number of Blue-throated Macaws measured for flight speed on survey dates

Date	Group Size	Distance(m)	Time(s)	Flight Speed
28/07/14	2	300	21.65	49.88
28/07/14	7	300	19.21	56.22
28/07/14	2	300	22.01	49.07
28/07/14	2	300	23.88	45.23
28/07/14	3	300	18.51	58.35
28/07/14	3	300	16.26	66.42
28/07/14	3	300	18.01	59.97
28/07/14	2	300	17.34	62.28
30/07/14	31	300	31.00	34.84
30/07/14	2	300	20.52	52.63
30/07/14	4	300	19.68	54.88
30/07/14	8	300	30.82	35.04
30/07/14	3	300	30.15	35.82
Mean:	6	300	22.23	50.82

Table 4.13 displays the date that recordings were taken on the Blue-throated macaw flight speeds. Here times were taken over a 300 metre distance and a flight speed was achieved from the formula; speed=distance/time. From this mean group size, flight time and flight speed was taken. Here it is shown that the mean group of macaws is 6, travelling at approximately 50.82km/hr.

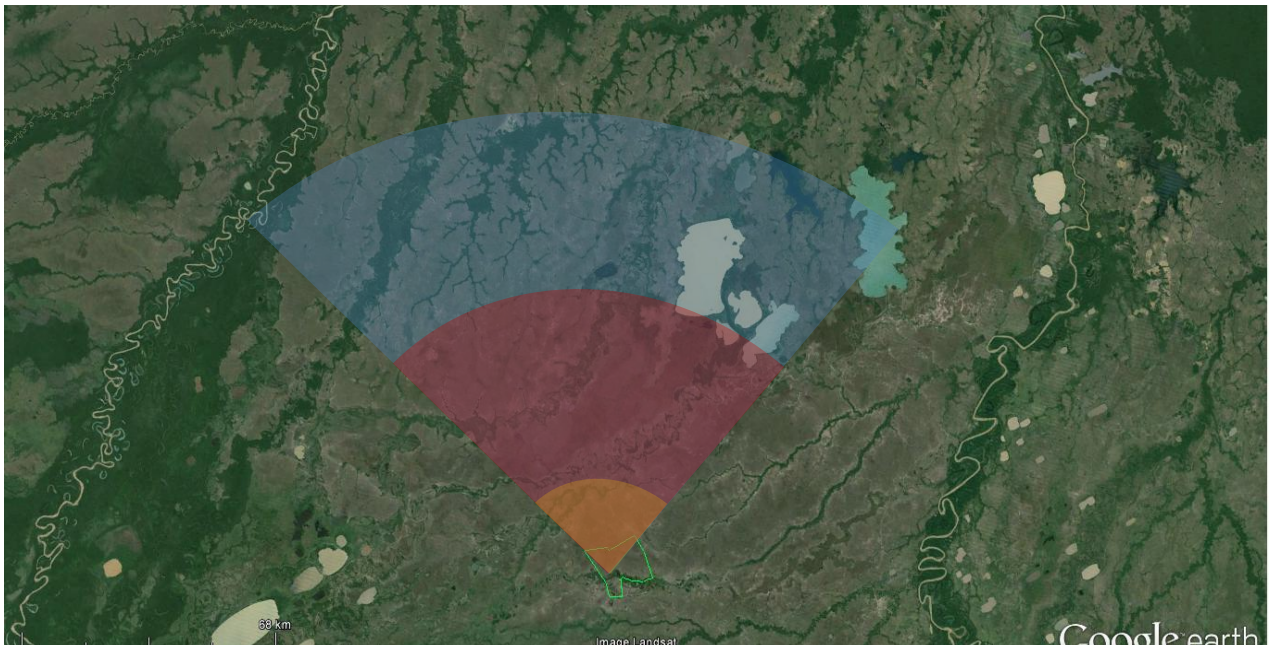

Figure 4.14: above displays the distance and area the Blue-throated Macaw could cover when leaving to roost at different times, assuming they are at roost sites by 19.00pm. Yellow denotes those leaving at 18.30. Red denotes those leaving at 17.30pm. Blue denotes those leaving at 16.30pm. The leaving point in this case is location BT, and the area covers between NW-NE, directions macaws were seen taking.

In the figure 4.14 above the distance travelled by the Blue-throated Macaw can be seen. The area covered spans from NW-NE which are flight directions often seen by this species. The reserve boundary is marked in green. The area marked in yellow shows a distance(25.41km), and area(506.85Km2) which can be covered by these macaws when leaving for roost sites at 18.30(assuming that macaws are all at roost sites by 19.00). The area marked in red shows the distance(76.23km) and area(4,561.65km2) that can be covered if macaws left at 17.30 in search of roost sites. The area marked in blue shows the distance(127.05km) and area(12,671.24Km2) that macaws could cover in search of roost sites if they left at 16.30. The leaving location used in this figure is BT5 in Barba Azul Island, as it is a common site to see departing Blue-throated macaws. It was found that it is

statistically close to significance that Blue-throated Macaws that larger groups of macaws have a decreased

4.3. Roosting Locations of the Blue-throated Macaw and the Blue and Yellow Macaw

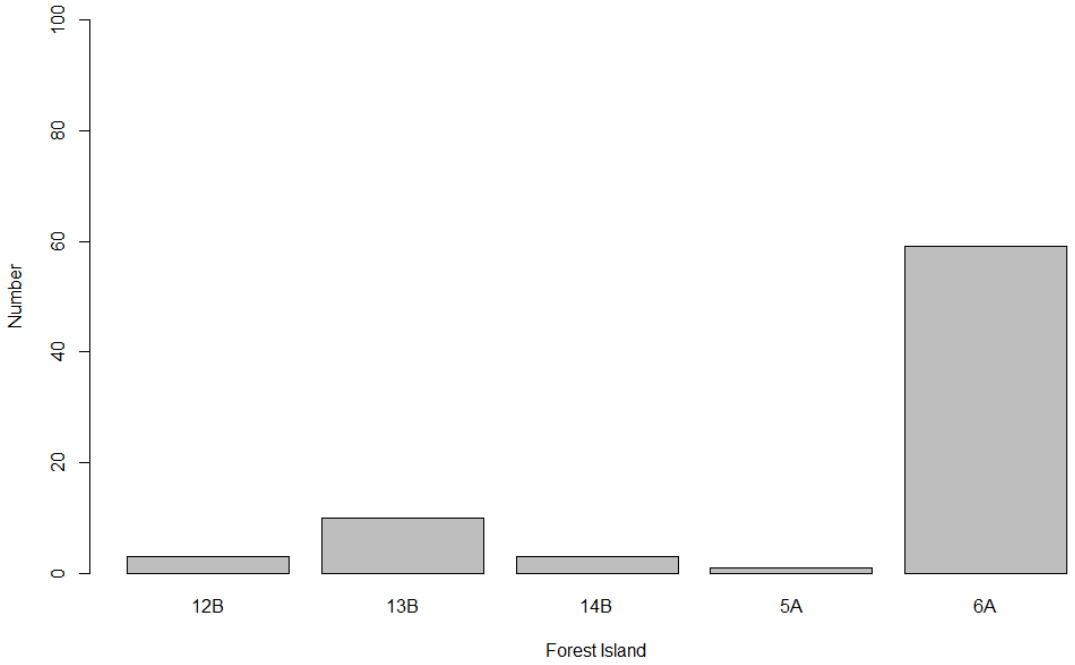

Figure 4.15: numbers of Blue-throated Macaws observed arriving at roosting Islands displayed on a bar plot

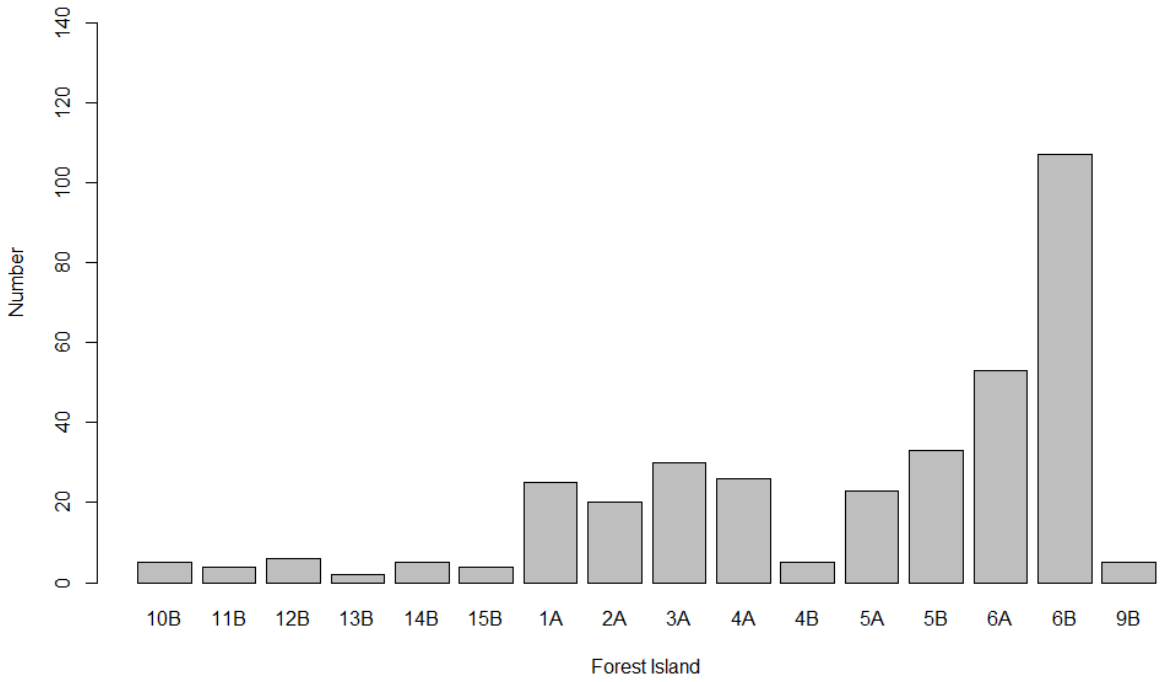

Figure 4.16: numbers of Blue and Yellow Macaws observed arriving at roosting Islands displayed on a bar plot

It is observed that only 5 forest islands in the reserve are being used by Blue-throated Macaws for roosting (As seen in figure 4.15). It is also noted that two of these islands are used by a considerable number of the species. Island 6A showed the most with 59 individuals using it, Island 13B was also used by many with 29 being observed utilising it. The other three islands showed much lower numbers with ten individuals or lower using each.

For the case of the Blue and Yellow Macaw, the roost island usage was much more dispersed with sixteen forest islands being observed as being roost islands for this species (As seen in figure 4.16). Eight of these islands showed a considerable number of individuals using them, with numbers surpassing twenty. Island 6B (n=107) and Island 6A (n=53), showed a very large number of roosting macaws. All other forest islands showed low numbers of macaw presence (n>10).

4.4. Motacu Tree Measurements and Regeneration Plots

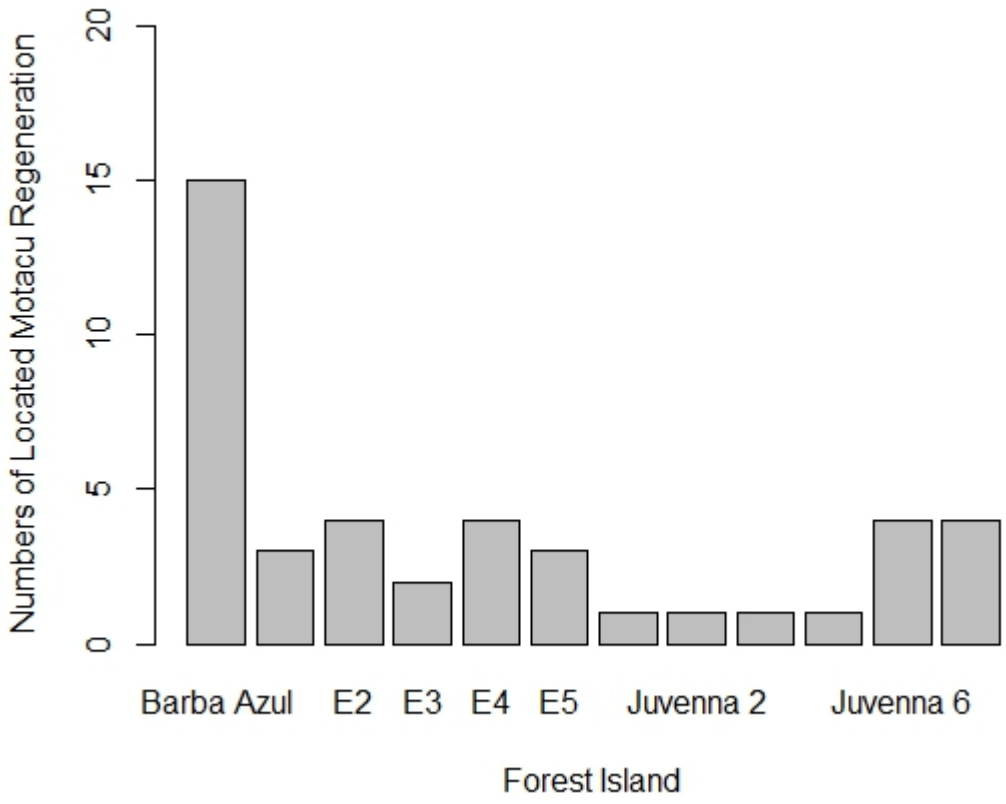

Figure 4.17: The amount of Motacu regeneration observed, in different forest Islands on the Barba Azul Reserve

It is observed that there is a large amount of Motacu regeneration in the large Barba Azul Island in the Western section of the reserve and it is much higher than it is found in other areas of the reserve. It is also noted that there is few regeneration in many of the Juvenna Islands, apart from Juvenna 6. In the East All the Islands show an average amount of regeneration. This information is displayed on a bar plot in figure 4.17 above.

Table 4.14: Displays the proportions of Non-fruiting, fruiting, and feeding Motacu palms across the Barba Azul Reserve

Island	Non Fruiting	Fruiting	Feeding	% Non-Fruiting	% Fruiting	% Feeding
Total Barba Azul	353	36	11	88.25%	9.00%	2.75%
Total W1	47	3	0	94.00%	6.00%	0.00%
Total Juvenna 1	182	16	2	91.00%	8.00%	1.00%
Total Juvenna 2	99%	1	0	99.00%	1.00%	0.00%
Total Juvenna 3	47	3	0	94.00%	6.00%	0.00%
Total Juvenna 4	96	4	0	96.00%	4.00%	0.00%
Total Juvenna 5	94	6	0	94.00%	6.00%	0.00%
Total Juvenna 6	87	9	2	87.00%	9.00%	2.00%
Total E1	83	14	3	83.00%	14.00%	3.00%
Total E2	90	6	4	90.00%	6.00%	4.00%
Total E3	97	3	0	97.00%	3.00%	0.00%
Total E4	79	19	2	79.00%	19.00%	2.00%
Total E5	72	27	1	72.00%	27.00%	1.00%
Total West	**400**	**39**	**11**	**88.89%**	**8.67%**	**2.44%**
Total Juvenna	**605**	**39**	**4**	**93.07%**	**6.00%**	**0.93%**
TotalEast	**421**	**69**	**10**	**84.80%**	**13.80%**	**2.00%**

A paired- t-test was completed to compare the Motacu Tree height and that of Motacu Diameter. The results showed t= 17.6929 and p= < 2.2e-16. This means that it is significantly significant that taller trees have larger diameters.

In table 4.14 above is displayed the proportions of non-fruiting, fruiting and feeding Motacu palms found on walkthroughs in the main islands in the southern section of Barba Azul reserve. It is found that there is 8.67% of the palms in the west fruiting with 2.44% being used as feeding trees. In Juvenna 6.00% of the palms are fruiting with only 0.93% of

the palms being used as feeding trees. In the East, there is the highest number of fruiting trees with13.80% found bearing fruits. 2.00% of the palms in this area are used as feeding trees.

4.5. Assessing Characteristics of Forest Islands

Table 4.15: Displays assessed characteristics of northern forest islands of the Barba Azul Reserve

Island	Motacu Regeneration	Freshly Eaten Motacu	Fruiting Motacu	Motacu Present	Evidence of Cattle	Wolf Apple Present	Palms Clipped	Macaw Feathers Present
W1	1	1	1	1	1	0	0	1
1A	0	0	1	1	1	0	1	0
2A	0	0	1	1	1	0	1	1
3A	0	0	1	1	1	0	0	0
4A	0	0	0	1	0	0	1	1
5A	0	0	0	1	0	0	1	0
4B	0	0	0	1	1	0	1	0
5B	0	0	0	1	1	1	0	0
6B	0	0	0	1	1	1	1	1
7B	0	0	0	1	1	1	1	0
8B	0	0	0	1	1	1	1	0
9B	0	0	1	1	1	0	1	0
10B	1	0	0	0	1	0	0	0
11B	0	0	0	1	1	1	1	0
12B	0	0	0	0	1	1	0	0
13B	0	0	0	1	1	1	1	1
14B	0	0	0	1	1	1	1	0
15B	0	0	0	1	1	1	1	1

Table 4.15 above displays the characteristics of many of the small forest islands of the Barba Azul reserve. All islands except W1 are found in the very northern area of the reserve. It is noted that many of the forest islands did not show any degree of Motacu palm regeneration in areas where there was a presence of cattle, or wolf apple tree. It was also noted that when there is a macaw presence, and clipped palms, Motacu never had evidence of fruiting. The only forest island with eaten Motacu is W1 which is situated very close to Barba Azul Island.

5. Discussion

5.1. Population Size and Structure

It was found that an average per survey that 37.6 individuals are seen flying over the forest islands, and 39.3 are seen leaving forest islands. This is relatively high proportion of the population of this species indicating the value of the Barba Azul reserve to this species. In terms of the Blue and Yellow macaw an average of 39.1 have been seen flying over, and 121.0 leaving, further evidence that during the dry season the dry season this reserve provides vital resources for different parrot species.

Through analysis of numbers and removal of double counts, it allowed us to be able to estimate the numbers of macaws leaving to roost. It is found that the numbers of Blue-throated macaw have doubled in number since the previous expedition (n=52), and nearly 100 more individuals (n=398) of Blue and Yellow macaws were observed (University of Glasgow Bolivia Expedition Report, 2012). These results also display a mean of 72.57 Blue-throated Macaws seen on every survey, compared to 30.80 observed from the previous expedition. Mean counts for the Blue and Yellow Macaw decreased slightly form a value of 323.40 to a mean of 320.86 being recorded this year. The results this year for the Blue-throated macaw were even higher also than those recorded in 2010(n=103), all of which were observed leaving the main Barba Azul Island (University of Glasgow Bolivia Expedition Report, 2010), making it the highest count ever recorded for this species in the reserve.

A significant contributor to the high counts achieved in this year is most likely due to the doubling of the reserve area. The increase in the reserve size has allowed for more survey areas to be covered and allow for an increased count number. Higher results seen in 2010 may

have been a result of high periodic fruiting Motacu palms in the main Barba Azul Island, whereas numbers in the 2012 expedition may have been lower due to different food availability in the region. This might explain lower numbers found in 2012, since the macaws of this region are dependent on fruiting Motacu, which is their primary food source. This may alter macaw population counts made by the past two University of Glasgow expeditions (2010, 2013).

Flight directions observed for both species show a very high proportion of individuals flying in a northerly direction for roost sites. The majority of the Blue-throated Macaws were observed flying directions varying from between Northeast and West. This information is similar to observations made by the past two expeditions, so the assumption that Blue-throated macaw roost sites are north of foraging sites is considered accurate.

The Numbers of which direction macaw took for roost sites is assumed to depend on the location within the reserve. Many individuals flying from the Western surveys were observed flying either north or in a North Easterly direction, with some individuals flying North West. In the Eastern part of the reserve a high numbers flew North, North West or West. It is thought that the probable reason for this may be due to the use of similar roost sites, because of their location they will have to take different directions to reach the roost sites. It is likely that both groups of macaws are meeting at similar roost sites in the northern Beni forest islands, and so it is assumed that both groups will be using similar roosting sites, though they may have different pre-roosting behaviour. Additionally it was found to be statistically significant that there is an increased number of individuals fluting North West for roost sites, further evidence that their roost sites are located in the north of their foraging sites.

Blue and Yellow Macaws showed a more dispersed flight activity with directions of greater variety in comparison to the Blue-throated Macaw. Many flew Northerly but also South and South West. This may be because of their large numbers; not all would be able to utilise the same roost sites in the north. It was found however, similarly to the Blue-throated Macaw that it is statistically significant for the numbers observed flying North/North-West. Like with other macaws, they were observed to congregate prior to leaving to roost, however to a higher degree than the Blue-throated Macaw. This may explain the larger numbers of Blue and Yellow Macaws flying South or South West, they may be flying to meet up with larger congregations before heading to roosting islands.

There is a considerable difference of pre-roosting behaviour when considering the distribution of the Blue-throated Macaw compared with the Blue and Yellow Macaw. It was found that in the West the Blue-throated Macaw primarily congregated at the very edge of the Barba Azul Island at BT5, and it was found to be statistically significant. The study found that prior to roosting, the macaws congregated in large emergent trees that tended not to be Motacu (Personal Observation). Parrots and macaws evolved flocking and flight speed to avoid owls and raptors which tend to be their main predators, and may be a reason for congregations observed pre roosting in this study (Costantini et al, 2008). Due to their smaller numbers the Blue-throated Macaw may congregate in one large group rather than splitting up like the Blue and Yellow Macaw, which could explain a large congregation at one emergent tree.

High numbers of the Blue and Yellow Macaw were observed in BT5, as well as much of the Barba Azul Island. Reasons for this might be that similarly to flight direction, they may not be heading to the same roost sites due to numbers. Their positioning on the reserve islands pre-roosting might be an indicator of which direction they will be heading in and what roosting

site they may be using. It was found on the reserve count survey, many Blue and Yellow Macaws were observed flying North from BT6 which was found to be statistically significant, a reason may be that a larger proportion of the Blue and Yellow Macaw reserve population may be using foraging sites to the south of the reserve.

Group size which was observed during surveys displayed large proportions of both species leaving in smaller groups, this could be explained by the different forest islands the species are using for roosting, if it is a further away island, they may be departing at different times to secure roosting sites. Different characteristics may also be considered not just between species but also between individual groups within the population. There may be some that preferred to use the safety in numbers hypothesis, where others may not. Further studies may be able to deduce the reasons behind group leaving patterns within the reserve macaw species.

The effect on weather shows that there is no significance that there is an effect of weather of the macaw species that were studied. It was noted however that on the entire reserve count that fewer numbers of Blue-throated Macaws were observed than expected and may be attributed to the poorer windy conditions of that date. It has been found in a study that in Chestnut-fronted macaws(*Ara severus*) and Red-bellied macaws(*Orthopsittaca manilata*) in the Tambopata National Park , Peru, that they show 29% less numbers in poor weather conditions, when they are going to a clay lick (Brightsmith,2004). This could be similar with the Blue-throated Macaws, and they may be leaving to roost early to avoid the poor conditions when it cools down at dusk, causing lower numbers to be observed during population counts.

It was found, however, that Blue and Yellow Macaw numbers were similar to be expected, it could be supposed that the two macaw species may react differently to differing weather conditions, yet it was expected that both species would display similar behaviour. To understand the effect of weather in more depth, multiple surveys will need to be completed in different weather conditions in the dry season. This could then help us understand how well macaw species in the Barba Azul Reserve react to poorer El Nino conditions.

The results show that there is a very high number of both species seen flying in groups. The bar plot above demonstrates that the highest group of two or three for both species. This means that a high proportion of the family groups have a successfully fledged young.

The results show that for the Blue-throated Macaw, there is a mean proportion of 23.8% of young in the population with 40.6% of the families breeding, and the Blue and Yellow macaw showed 23.6% across all the surveys, with 40.2% of families breeding. The similar figures for both species is an indicator that the results are fairly accurate. This is a very high proportion of a population to have new fledged young for a large avian species. Studies in Peru have shown that the sympatric Blue and Yellow Macaw only have a fledging success of 0.5 young per nest (Brightsmith and Bravo, 2006). The information found in our study, on the breeding success of both the Blue-throated Macaw and the Blue-and Yellow is a clear indicator that breeding sites for these species must be rich and provide very successful numbers of macaw fledging. However, the future for the Blue-throated Macaw's protection will be to make the Barba Azul Reserve more attractive as a nesting ground, and it is an important feeding source during the dry season. Remaining

the in the reserve for feeding and nesting would decrease the risk of poaching. In non-protected areas all age classes of macaws are at risk, eggs, young and adults are taken for the illegal pet trade (Guedes, 2004).

It is though, that the main limiting factor for breeding in tropical birds is nest site availability- this is a particular problem for macaws and other parrots. The reason for this is the requirement for tall trees that have hollows within them or tall dead palms; which can be hard to come by (Renton, 2004). A solution Asociacion Armonia can get round this will be the placing of man-made nest sites, such as nest boxes. Boxes of different sized openings would decrease the competition between the two main macaw species on the reserve. The use of the nest boxes might not only further the protection of this species by keeping them in the protected reserve, but also increase the breeding success due to the rich ecosystem.

5.2. Flight Behaviour of the Blue-throated Macaw

As can be seen in the results there is an average flight speed of 50.82Km/hr shown by the Blue-throated macaw over a 300 metre flight path. The study found that the highest flight speeds were 66.42 Km/hr, while the lowest were 34.84 Km/hr. The difference between group size and flight speed shows that it is almost statistically significant that, macaws flying in larger groups tend fly at a slower rate, however more data will be required to achieve more accurate results.

These results are similar to that of flight speeds of other macaw species. Other studies completed in Bolivia have found that the smaller Red-fronted (*Macaw Ararubrogenys*) have

shown to achieve a normal flight speed of 60kph. It is noted that like the Blue-throated Macaw, this is a highly sociable species, and group size may have an effect on the speed of its flight (Boussekey et al, 2010).

Another closely related species is the Scarlet macaw (*Ara macao*). This species, although, is more commonly found in a tropical rainforest ecosystem, have, through studies an estimated normal flight speed of 56.327Km/hr, a very similar speed to that of the Blue-throated macaw (UWI, 2001). This can be attributed to the similarity of their wing structure and profiles and life strategies. They show similar flight and foraging behaviour to the Blue-throated macaw, (e.g. leaving at dawn to feed on palm nuts), contributing to their flight behaviour and speeds recorded.

This information on flight speed is crucial to the conservation of this species as it allows us to calculate flight distances in, and outside of the Barba Azul reserve. It has been calculated from the information gathered on the flight speeds, and flight directions the possible area that this species might be using for roosting. Those departing from BT5 in the Barba Azul Reserve are likely to travel a distance of 127.05km, and cover an area of 12,671.24Km^2 if Blue-throated macaws were to depart at 16.30. If they were to depart at 17.30 they could travel a distance of 76.23Km and cover an area of 4,561.65Km^2. Those departing at 18.30 could cover an area of 506.85Km^2 and reach distances of up to 25.41Km. Although those leaving at 16.30 have the possibility of covering a very large distance, it is unlikely that macaws will do this. The majority of macaws left from 17.00 onwards and it is believed that they would arrive at roost sites prior to dusk. If Asociacion Armonia wants

to purchase land, to protect macaw roost sites, ranches just north of the reserve boundary could possibly be a good site, to preserve more possible roosting islands.

Furthermore if Blue-throated Macaws are flying the maximun possible distance from our study, it could show the importance of the Barba Azul reserve as foraging site for this species in the dry season. Covering a possible area of 12,671.24Km^2 to reach the reserve from roost sites is good indicator in the quality of forgaing sites in this reserve.

5.3. Roosting Behaviour of Blue-throated Macaw

Analysing the flight behaviour information and that of flight direction in population studies, allows a good comprehension of the likely area being utilised by the Blue-throated Macaw for roosting sites. As can be seen by the results, roost sites were found mostly within the projected area on the Barba Azul Reserve, with the main roost site just outside this boundary. The preference of this roosting might not be so important for the Blue and Yellow Macaw and they seem to have roost sites spanning throughout the reserve.

There may be reasons that may explain this, as it is known that there is competition between macaw species, especially during the breeding season. It was found that in the Tambopata National reserve in the Peruvian Amazon, that there is strong competition for nest sites between the Blue and Yellow Macaw and the Red-bellied Macaw (*Orthopsittaca manilata*). In these cases the Red-bellied Macaw are often unsuccessful; as the species is much smaller, it cannot compete with the larger Blue and Yellow Macaw (Brightsmith and Bravo, 2006). Similar behaviour has been indicated in the Barba Azul Reserve, as a Blue-throated macaw had been seen dead under a nest box, it is believed to have been due to

competition with the Blue and Yellow Macaw (Bennet Hennessey personal comment). For competition for foraging sites, it is thought that there is not such a big impact in foraging sites. This is because macaws generally do not feed in trees of the same genera so competition is reduced in highly productive areas (Brightsmith and Bravo, 2006). It has been found; however, in the Manu Biosphere Reserve that certain macaw species do compete against other parrot species when there is a low food resource, as has been witnessed at clay licks (Burger and Gochfeld, 2003).

Roosting, observed in the Barba Azul Reserve by the macaw species has been found to be communal roosting. It is noted with other avian species that those that use roost sites are often highly sociable family groups or feeding groups which seems to both be the case in macaws (Ward and Zahavi, 1972).

Parrots especially have been known to roost together in large numbers where the food source is unevenly distributed. This is the case in the Barba Azul Reserve, where food sources for the Psittacidae family is limited to the Motacu palm. This palm which is the dominant palm species found both within and outside the reserve does not all fruit at the same time, causing a mixed distribution of feeding palms throughout the reserve (Ward and Zahavi, 1972).

The slight competitive nature of the macaw species and the high numbers present in the reserve could potentially lead to interspecific competition. This could be a reason for why there is a difference in the distribution of the Blue-throated Macaw throughout the reserve, due to competition and ecological pressures. As can be seen in the results the Blue-

throated Macaw appear to group together in a roost site on a forest island far north in the reserve. This may not be a favoured forest island but they may be out-competed, so are restricted to islands at a further distance from the food sources. They may also roost in different locations so that they will not leave in large numbers for the same food source (Chapman et al, 1989). The Blue and Yellow Macaws show a more distributed roost pattern in forest islands closer to feeding islands due their numbers and competitive nature. Therefore they may have preferred different roost site locations, and are less restricted to feeding in the same forest islands.

5.4. Motacu Tree Measurements and Regeneration Plots

It can be observed in the figure above that there is a considerable increase in the number of regeneration in the main Barba Azul forest island in the western section of the reserve. This could be due to the fewer number of cattle present. The size of the island could also be a reason for an increased number of regeneration; cattle will probably focus on certain areas so not all the Motacu regeneration will be trampled. In the Eastern area of the reserve there is a considerable reduced amount of regeneration. There is an increase in the number of cattle on the eastern section due to it being still ranch land. However the cattle are kept enclosed which should reduce the amount of regeneration which is destroyed. In the Juvenna section of the reserve there is a distinct lack of regeneration. This is probably caused by the large number of cattle in that section of the reserve. The cattle are not kept in enclosures so would probably enter the smaller forest islands to cover from the sun during the heat of the day, or to rest at night. It is observed in all three sections of the reserve that larger forest islands tend have a much higher regeneration due to cattle not completely

covering the forest islands. Regeneration may not be able to occur in smaller islands in the future unless the cattle are removed from the reserve.

A t-test was performed and which found that tall Motacu commonly have a larger diameter. It is also found that on that taller palms with larger diameters tend to be feeding trees. Statistically this is not significant, however more studies will be required to understand this fully.

If it is found to be significant this may mean that the protection of these palms to be of crucial importance. Due to the lack of research we do not know how long these palms fruit for or how large they have to be to fruit, so it is very important that we increase our knowledge of regenerating palms and the ones already of a considerable size within the reserve. If the fruiting trees were to be eliminated it could be catastrophic the macaw species which use the reserve, as it is their primary foraging site.

As can be seen in the table above we get an impression of the proportions of the Motacu palms that are being used at any one point within the reserve study areas. It is found that in the West 8.66% were observed to be fruiting and 2.44% were being actively used as feeding trees. In the East 13.80% were fruiting with 2.00% used for feeding. Juvenna showed 6.93% fruiting and 0.93% being used as feeding trees.

This could explain the distributions of macaws seen in the population counts. The Western and Eastern sections of the reserve show very high numbers of both species and this could be linked with the food sources. Between 8-13% of the Motacu which were within the study areas were fruiting and about 2% were fruiting at any one time. No Blue-throated

macaws were observed flying over the Rio Omi from Juvenna and this could be linked to the lower number of fruiting and feeding trees present at that section of the reserve.

An explanation for low signs of feeding trees may be attributed to cattle, evidence has been found in bovine faeces that they do consume Motacu, thus they may be eating Motacu already partially consumed by a macaw species and altering the results obtained.

It is possible that at the time of the study and the study area chosen that there may not many fruiting trees, and so it is important that research on the abundance of fruiting trees should be completed in the future, and this will allow comparisons to be made between years and it will, as well as providing the Asociacion Armonia with data regarding the numbers of fruiting and feeding Motacu present. If there are indeed reducing numbers of fruiting and feeding Motacu, solutions could be found in order to save the palm such as designated areas for regeneration fenced off by cattle, if the removal is not possible in certain areas. If solutions like these could be made to save the palm which provides a vital food source for the macaw species of the region.

5.5. Assessing Characteristics of Forest Islands

Through the analysis of the northern forest islands, similarities could be made and reasons for the lack of Motacu regeneration could be deduced. It was found that out of the 18 forest islands that were examined, 10 contained the wolf apple (*Solanum lycocarpum)*. This species was observed to be very dominant in the forest islands, with a tree dominating the centre and obvious regeneration surrounding it. It could be that the regeneration of the wolf apple can be out-competing the regeneration of Motacu palms. It was also noted that in many of the forest islands with no fruiting Motacu, and no eaten Motacu tended to have

clipped palms caused by macaws. This could be a reason that there is no regeneration, since there is never fruit available for regeneration as they are removed by macaw species for roosting. A very large issue in all of the Barba Azul reserve is the presence of cattle which enter forest islands in the hottest parts of the day; they may be crushing the regenerating Motacu due to many entering small forest islands. A manner of solving the problem with the lack of regeneration in the reserve will be the removal of cattle. The cutting back of the wolf apple will not be possible since it forms 40% of the vegetable diet of the maned wolf(Aragona and Setz, 2001) already considered a near threatened species(IUCN, 2014), and like with the Motacu palm there are few studies of its ecology. However, It is more likely that the cattle in the major contributor to the lack of Motacu regeneration.

5.6. Conclusions

During the study the Blue-throated macaw was recorded to have a minimum population of 111 individual utilising the reserve. A whole reserve count however showed a much lower value of 83 individuals. According to the IUCN redlist the entire world population estimate of the Blue-throated macaw could be up to 130 individuals making our count of 111 individuals 85.38% of the world population, and the count of 83 individuals, 63.85% of the world population. Whichever stands more accurate it is quite clear that the Barba Azul Reserve is a stronghold of a very large proportion of this critically endangered species. After additional purchases of land in the future by Asociacion Armonia it is possible that new populations of this endangered species may be found, and the current world population may be underestimated. Nevertheless the high numbers recorded in the study

is important for Asociacion Armonia as it shows that this species is recovering naturally in the wild due to its conservation.

The data provided about the numbers of young fledged Blue-throated Macaws, and Blue and Yellow Macaws acquired by this study, is crucial to Asociacion Armonia for understanding the population structure of this population. Both macaw species that were studied showed about 20% of the population to be made of fledged young. Continuing population surveys and family group surveys could allow for Asociacion Armonia to understand the yearly survival rates for fledging macaws. If similar proportions occur each year it could be possible to understand the population trend in more depth.

Additionally, the placing of nest boxes could be a priority for Asociacion Armonia. Boxes of varying entry sizes could reduce competition for nest sites between species and maintain this fragile Blue-throated Macaw population in the reserve.

Combining the study of Blue-throated macaw flight behaviour and roosting behaviour has proved has allowed a greater understanding of the roost a large proportion of this reserve's population. This gives Asociacion Armonia information of where would be best to consider a new ranch purchase to protect the species. More research is required in order to confirm the estimated roost sites. Although they are species with regular habits, it is not certain that the islands found are used frequently as roost sites. Further surveying could shed more light on this, and potentially influence Asociacion Armonia in their next purchase. An initial act for this conservation group will be to secure the forest islands

observed being utilised by the species, one of which is just outside the boundary of the reserve.

There seems to be a mosaic of Motacu palm regeneration it to a higher degree than others. The main reason for this is assumed to be the presence of the cattle in the reserve. It is vital that Asociacion Armonia removes the cattle from the reserve as it is limiting Motacu regeneration greatly. There have not been many studies completed in the growth of the Motacu palms and thus there is a concern with the lack of regeneration. Studies need to be completed to understand the length of time that these palms can fruit for, thus how long the current fruiting palms remain a feeding resource for many species. After this measures may be able to put in place to protect the regenerating palms, which will eventually provide a rich food resource for years to come.

It is obvious that more frequent surveys are needed to try and secure the most information possible on the Blue-throated Macaw. Completion of this would provide an accurate estimation of the population size, rather than pure estimates. Surveys on the fledged young are very important and continual surveys during the dry season will state whether the population is increasing in the wild. Concerning the current study, it has shown that the Barba Azul Reserve is providing a rich habitat for the Blue-throated Macaw, and could prove to be a stronghold to the recovery of this critically endangered species, and many other species of order Psittidae which are at risk.

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8. Development of the Project

Past expeditions have completed population counts on the two species of macaw in the reserve, and have studied their food source- the Motacu palm. In this year's study and the enlargement of the reserve it was a clear opportunity undertake further surveys of macaws in the new section of the reserve, helping Asociacion Armonia with their population surveys. Due to the information provided by previous expeditions, western population count locations were fairly easy to select.

Additionally, an aim for this project was to study the pre-roosting behaviour and we had the opportunity to venture in the north and study the northern islands for actual roost sites for both species. Prior to this we studied the flight speed of the Blue-throated Macaw. In terms of roosting surveys, limited time meant that only few surveys could be completed. It was decided to complete one survey on every northern forest island, rather than multiple surveys on fewer locations, completing this would allow us to conclude whether the Blue-throated Macaw, and Blue and Yellow Macaw roost on the reserve.

In relation to the Motacu palm study, transects in all large feeding islands which are assumed to be the foraging islands to the species were studied. Due to the lack of time, only a few transects were completed per forest island, in order to have some sort of coverage across the whole reserve.

The analysis was completed by using R-studio which involved a long period of time in achieving the ability to accurately analyse the results obtained throughout the study.

9. Appendices

All raw data can be seen in the disk attached with this report.