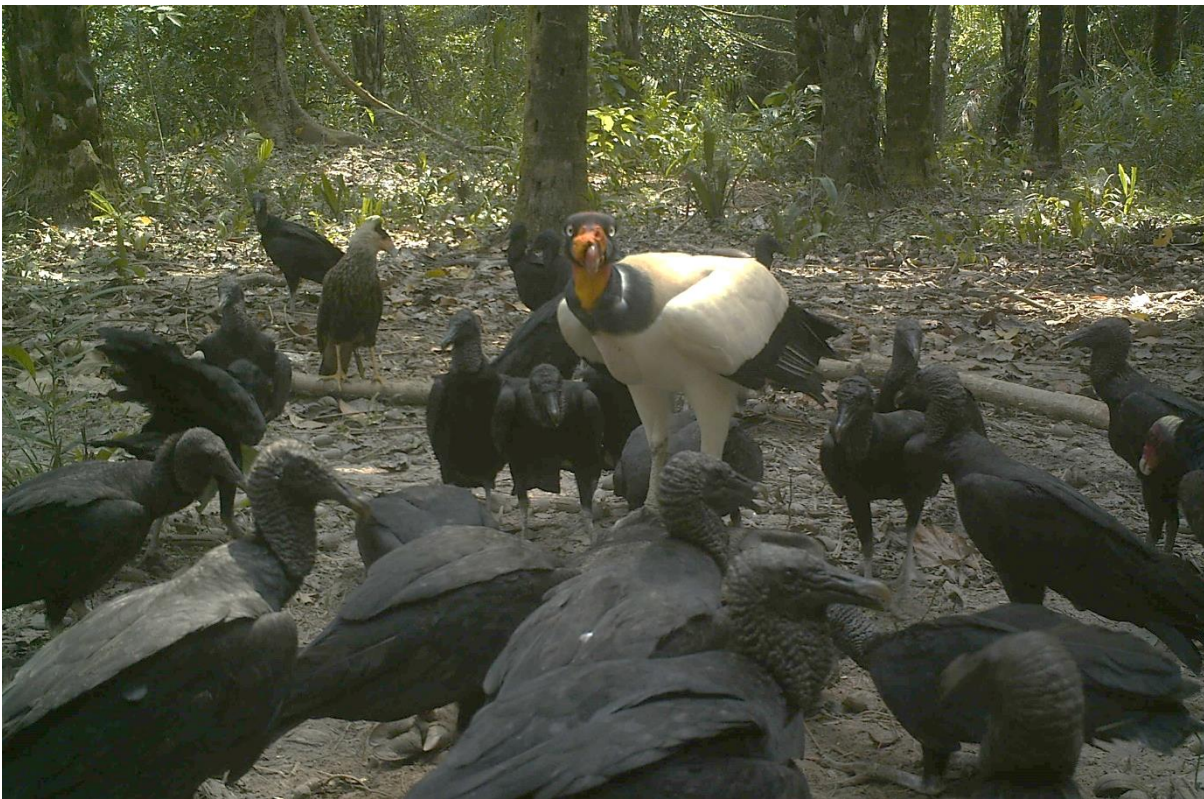




University of Glasgow

The habitat preferences and impacts of cattle ranching in scavenging populations in the Barba Azul Reserve, Beni Department, Bolivia.



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Level 4 Honours Project

Abstract

A global decline in scavenging species poses a threat to global ecosystem functioning, and a lack of scientific understanding on the habitat preferences and impacts of ranching on scavenging doesn't reflect the importance and ubiquity of the role that vultures and other scavengers play. The aim of this study was to try and better understand the habitat preferences of scavenging species, and to see how the presence of cattle ranching may affect the abundance and distribution of scavengers. The habitats analysed included forest, riverside, long grass and short grassland. A total of 12 baited camera traps recorded the number of individuals over a two-month period in the Barba Azul Reserve, Bolivia. Interestingly the abundance of scavengers was greater in an area with cattle ranching compared to a non-grazed area; the data revealed that birds showed a significant preference and mammals showed a preference for unforested areas. A total of 12 species of scavenger were recorded, with black vultures (*Cathartes atratus*) being the most abundant scavenger on the reserve, with birds being the dominant taxonomic class in terms of scavenging; as the abundance of mammals was relatively low, with only 23 recorded individuals. Some of the species included in the study include: king vulture (*Sarcoromphus papa*), collared peccary (*Pecari tajacu*), black vulture (*C. atratus*), crab-eating fox (*Cerdocyon thous*) and cooi heron (*Ardea cooi*).

I conclude that birds in the Barba Azul Reserve show a preference for forested habitat and areas with cattle ranching, however further studies are needed to determine annual scavenger abundances. The importance of this study is reflected in the importance of the scavenger; without them the ecosystem functions they provide are compromised, with consequences to global ecosystems.

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Introduction

Increases in deforestation, globalisation and urbanisation are leading to significant losses of biodiversity across the globe (Dirzo and Raven, 2003). With a decrease in biodiversity in ecosystems, ecosystem functions and the services they provide are also in jeopardy. Those species at risk are not only the apex predators and their prey but also the scavengers. Scavenging is a behaviour characterised by the consumption of already dead material, in this instance it refers only to the animal scavengers (Getz, 2011). Scavenging is a diverse and ubiquitous life history strategy for many species, including spotted hyena (*Crocuta crocuta*), which are documented to scavenge and steal recently killed prey from other predators, or, bearded vultures (*Gypaetus barbatus*) whose diet consists primarily of bones (Abay et al., 2010; Hiraldo et al. 1979).

Understanding the role that scavengers play in an ecosystem is of significant importance, as scavengers provide vital ecosystem services by consuming carrion (Beasley, Olson, & DeVault 2015). As such, scavengers connect food webs, as they facilitate the distribution of nutrients within and between trophic levels and ecosystems and in many food webs a greater amount of energy is transferred through scavenging than through predation (Huijbers et al., 2013; Reimchen et al., 2002; Rooney et al., 2006; Wilson & Wolkovich, 2011). Moreover, scavengers aid the removal of carrion which allows to remove potential disease reservoirs from the environment. This is important, as carcasses left unconsumed allow the accumulation of zoonotic pathogens and putrefactive bacteria and can become reservoirs of disease for humans, livestock and wildlife (Monroe et al., 2015; Ortiz & Smith, 1994; Sterne & Wentzel, 1949; Reed & Rocke, 1992; Vass, 2001).

Interestingly in a terrestrial context vultures are the only obligate scavengers, surviving solely on carrion. Vultures are able to occupy this niche for a number of reasons including; relatively large body sizes allow the birds to survive off their body reserves when food is sparse; whilst their broad wingspans allow for energetically favourable soaring, enabling them to search large areas for carrion (Ruxton and Houston, 2004). Despite these adaptations, the scavengers most at risk from extinction are vultures; with one study finding that nine of the 22 vulture species are critically endangered, three species are endangered and four are near threatened (Buechley and Şekercioğlu, 2016). Yet, the ecology of scavengers and their role in ecosystems has been difficult to study for several reasons, such as the human aversion to decaying matter, difficulties in differentiating between scavenged and depredated material, and that many species are opportunistic scavengers making it difficult to isolate the level of scavenging in their diet (DeVault et al. 2003).

Vultures provide important ecosystem services, but are in decline. Yet, as vulture populations decline, increases in other scavenger populations, such as rats and feral cats may have significant socio-economic impacts, including the spread of disease. Additional reasons for conserving vultures include the preservation of cultural practices; in areas of India, vultures play important roles in the Parsi religion, which prohibits the burial or cremation of their dead, instead 'sky burials' are carried out whereby bodies are left to be naturally removed by vultures. Since the decline of vultures there are now difficulties in discarding their dead whilst still maintaining their religious practices (Markandya et al., 2008).

Despite their importance within ecosystems, scavengers are significantly affected by anthropogenic impacts, including poisonings, collision with anthropogenic structures, habitat degradation and habitat loss. Vultures are particularly vulnerable to poisoning due to the life

history strategies of the birds (Houston, 1996). The obligate nature of their scavenging increases the likelihood of consuming or being exposed to contaminants and the communal feeding of vultures also exposes multiple individuals at the same carcass (Ogada, Keesing and Virani, 2011). In many cases, the poisoning of scavengers has been non-intentional, yet vultures have been deliberately persecuted, as they have been historically viewed as “symbols of backwardness, infection and filth” (Bullock, 1956). Poisoning of vultures by ingestion of nonsteroidal anti-inflammatory drugs, particularly diclofenac-sodium, has caused severe population declines in Asian ‘*Gyps*’ vultures in only a few decades (Oaks et al. 2011). Similarly lead poisoning through the ingestion of pellets or lead-based bullets, through the consumption of carcasses killed by human hunters, is a serious threat to some vulture populations, most notably the California condor (*Gymnogyps californianus*) (Rideout et al., 2012). Poison and persecution are not the only threats to vultures and scavenging birds, collisions with anthropogenic structures such as powerlines and wind turbines also pose a threat (Markus, 1972; De Lucas 2008). The adaptability of scavengers means there are large populations of scavengers, including vultures, which are thriving in urban landscapes. However the city lifestyle poses new dangers for both humans and the animals. In the city of Ilhéus, Bahia, Brazil, the populations of black vulture (*Coragyps atratus*) and turkey vulture (*Carthartes aura*) increasingly face the dangers of colliding with aircraft, which in turn poses a threat to humans, as well as furthering economic impacts (Novaes and Cintra, 2015). In South America large numbers of vultures are adapting to an urban environment, but many vultures still live in their natural habitats.

Land-use changes and their interaction with other global changes have had a strong impact on the structure of biological communities (Leemans and Zuidema, 1995 and Hurtt et al., 2006; Rosenzweig et al., 2008 and Gil-Tena et al., 2009). A study into deforestation rates

found that one area of Bolivia had converted 88% of its natural landscape into agricultural land in less than 40 years, with similar rates in other developing areas (Redo, Millington and Hindery, 2011). There is little scientific consensus on how the loss of forests affects vultures, as the forested areas of Africa and Asia don't support vultures and these are the geographical areas where vultures are most studied; South American forests however do support vultures and yet minimal work has been conducted on the impacts of deforestation to vultures (Houston, 1986). In the Beni Department (see Figure 1), palm tree species such as the Motacu (*Attalea phalerata*) dominate forest islands and are impacted significantly by cattle herbivory on tree seedlings, a factor that when combined with intense soil compression, inhibits the growth of any regenerating trees in forest islands (Boorsma, 2016). The increasing rates of deforestation and the increasing pressures on the remaining woodland areas shows the importance of studies on vultures and other scavengers, as in many areas their role may be lost before the significance is recognised. Vultures that inhabit other habitats, such as neotropical savannahs, are also under threat as their habitat is altered. Neotropical savannahs, which are grassland biomes scattered with occasional trees, are particularly under increasing human pressure due to large-scale conversion of grassland habitats to pastures (Marris, 2005). Large areas of grassland in the Beni Department are purposefully burned annually to encourage the growth of fodder for cattle to feed on, increasingly this puts more pressure on the small areas of forest and also contributes to increased levels of nutrients being washed away via surface water run-off when precipitation falls (Boorsma, 2016).

Habitat loss affects species in different ways, for example turkey vultures (*C. aura*) rely on forest canopies to deflect winds which allows the vultures to soar over large areas to search for carrion (Houston, 1986). Black and turkey vultures also rely on the canopy and sub-canopy for perching sites, to avoid predation and also for nesting sites (Marion and Ryder 1975;

Preston 1990; Titus and Mosher 1981). The loss of forests therefore has the potential to impact vulture populations dramatically, although an increase in scientific study in this area is needed.

Overall, vultures and other scavengers, such as crab-eating fox (*Cerdocyon thous*) and southern crested caracara (*Caracara plancus*), both of which were included in this study, provide important ecosystem services; distributing nutrients or preventing the spread of pathogens through carrion consumption (Huijbers et al., 2013; Monroe et al., 2015). Although of importance to ecosystems, there have been global declines in scavenger populations for a number of reasons, one of which is habitat loss. Habitat loss is one of the leading factors in the decline of Old World Vultures (vultures found in Europe, Africa and Asia) as they lose valuable nesting sites. However to date there is still relatively little scientific information regarding vultures, and even less on the New World vultures of South America. One study however has highlighted that the main factor in the decline of king vultures is due primarily to habitat destruction (Bellinger, 1997). Despite the lack of research, the Beni savannah is a habitat that supports a number of important vulture species, including the king vulture (*Sarcorampus papa*) and the lesser yellow-headed vulture (*Cathartes burrovianus*). The presence of cattle ranching also provides an opportunity to test the effects of habitat loss on scavengers in a real-world environment.



Figure 1: Map showing the country of Bolivia, with the Beni Department highlighted in green and the red dot indicating the location of the Barba Azul Reserve

Aims and Objectives

As a field of interest, scavengers have not had the same level of interest as other groups of animals, nor has the habitat preferences they exhibit. Firstly, community assemblage was compared across various habitats in order to see if any key species influenced habitat preference in the scavengers. Community assemblages might then help to explain why certain species are found only in some areas and what the possible conservation implications are.

Furthermore, there is sparse information on the scavengers in the Beni Department, in particular respect to taxonomic class (bird, mammal, and reptile). In an area rich with all taxonomic classes of scavenger, this is an important aspect in both conservation and in our understanding of the ecosystem function.

Research was also undertaken into the relative abundances of scavengers in both forested and unforested areas. In the Beni Department, where forests are often fragmented, it is of importance to note whether these forest islands are of importance in a scavenging context;

as this could have a long-term impact on land use both in the Barba Azul reserve and elsewhere in the Beni Department or other neotropical savannahs.

Finally, the preference for forested areas or unforested areas and the impacts of ranching were studied. The eastern side of the Barba Azul reserve has been intensively ranched in the past, whereas the western side of the reserve remains protected from cattle. By looking at the relative abundance on the three most numerous species of scavenging bird: black vulture (*C. atratus*), turkey vulture (*C. aura*) and southern crested caracara (*C. plancus*), across ranched and unranchd areas, I also aimed to determine if ranching on a local scale positively correlates with lower numbers of scavengers.

Methods

The Barba Azul Reserve, located in the Beni Department, is an example of a protected area, with minimised grazing impact on one side of the reserve and with a population of sustainably ranchd cattle on the other side, separated by bordering fences. The area is rich in biodiversity, for example 300 species of bird can be found on the reserve year-round (Boorsma, 2016). The area represents other areas of the Beni savannah that have been untouched by ranching whilst also offering an opportunity to look at the impacts of localised ranching. The study in the reserve focused on the differences in the relative abundance of scavengers between forested and unforested areas as well as comparing the western and eastern sides of the reserve for species diversity and abundance; the eastern side supports a sustainable ranching program whilst the western side has minimised grazing pressures. While one of the original aims of the study was to assess habitat preference, problems in the field did not allow for appropriate replication to determine habitat preference of vulture species in this study.

Study site; Barba Azul Reserve

The location of the study was the Barba Azul Reserve, in the Beni Department, Bolivia (13° 45.733'S 66° 5.892'W). The reserve's landscape is dominated by Beni savannah, in an ecoregion known as the 'Llanos de Moxos' which covers approximately 110,000km² of the Beni region and is characterised as a region with many large open areas of herbaceous wetlands, grasslands, savannahs, and woodlands (Langstroth Plotkin, 2012). The area is considered unique in a biogeographical sense and is not part of the Amazonian Region (Navarro, 2002).

The 110km² reserve is owned by the NGO 'Asociacion Armonia', a partner of Birdlife International. In 2008 the reserve was created by the initial purchase of 36 km² of land (see Figure 2). The reserve was purchased with assistance from World Lands Trust (World Lands Trust United States, 2008) and the American Bird Conservancy group. The reserve was extended in 2010 to 47 km², with the addition of land to the south, in an area now known as 'Barba Azul Sud' (World Land Trust, Bolivia, 2014). In 2014 the reserve more than doubled in size, with the addition of neighbouring land in an area now known as Barba Azul Este, (Figure 2, green). This more than doubled the reserve size from 47km² to 110km². The western side of the reserve is dissected by the Rio Omi (Figure 2, blue) which separates Barba Azul Sud from Barba Azul Oeste. The more recently purchased Barba Azul Este was heavily ranched land, and is now maintained as part of a sustainable ranch by Armonia. The Rio Tiniji provides a water source in the north of the reserve during the dry season (Figure 2, purple).



Figure 2. Figure 2 showing the Barba Azul Reserve, 2016. The area marked in white is Barba Azul Oeste and Barba Azul Sud, with the Rio Omi flowing through it marked in blue. Barba Azul Este is marked in green with the Rio Tanihi in the north, marked in purple. Map created in Google Earth.

The Barba Azul reserve boasts high levels of biodiversity, a research expedition in 2009 estimated a total of 230 bird species present on the reserve, with the total having increased to 300 in 2016, including the first recording of a king vulture (*S.papa*) (Dickson and Kingsbury, 2009; Boorsma, 2016). The diversity of mammals is high on the reserve, including giant anteaters (*Myrmecophaga tridactyla*) and pampas deer (*Ozotoceros bezoarticus*). Additionally, ocelot (*Leopardus pardalis*) are known to breed in the area and big cat footprints are occasionally found. The reserve is also home to one of two sub-populations of critically endangered blue-throated macaw (*Ara glaucogularis*); for this reason alone it is an important biological reserve. Moreover, the reserve also contains numerous species of vulture, and other scavenging mammals, such as puma (*Puma concolor*) and crab-eating fox

(*Cerdocyon thous*). The study site therefore offered an opportunity to study scavengers in an ecosystem with numerous species of scavenger of different classes.

Experimental Design

Scavenger abundance was recorded using baited camera traps in several habitats common in the Beni; forest, river, savannah and short grass in both ranched and unranchd locations. Barba Azul Este (Figure 2, green) was formerly a heavily ranchd area with intense grazing pressure, since being purchased by Armonia the area now holds a smaller population of cattle as part of a sustainable ranching program (Boorsma, 2016). Forest habitat was determined as any site within the forest islands in the reserve. Riverside habitat was denoted as within five metres of a flowing body of water. Vegetation measurements distinguished between short grass and long grass, with an area requiring a mean vegetation height of over above one metre to qualify as long grass. Sites were found and allocated during exploratory transects, and were omitted if not accessible on foot or if there was no feasible way of securing the bait. When the bait was secured at a site; the time, date and GPS coordinates were noted using the Garmin eTrex personal GPS's (Garmin, 2007), using the datum WGS 84 (Xiang Shen et al., 2015). The fieldwork was conducted over the course of two months (02.07.16 – 02.09.16). Initially the study was carried out in the western side of the reserve (13° 45.613'S 66° 7.056'W) and from 11.08.16 the study was carried out in the eastern side of the reserve (13° 45.071'S 66° 2.690'W).

Figure 3 shows the locations of the samples in the study (Figure 3, yellow pins). Due to logistical constraints the study was only done north of the Rio Omi (Figure 3, blue). Red pins indicate baited sites that were omitted due to camera trap errors.



Figure 3. Figure 3 shows the locations of the sample sites used in the study. The sample site names refer to the bait type, habitat type, side of the reserve and number. Pins indicate sample sites, yellow indicates it was used in the study, red indicates camera trap malfunction.

Baiting and Camera Traps

Bushnell Camera Traps were used in the study, capturing 25 seconds of video and two photographs upon each activation. Night vision was enabled and set to medium sensitivity. The period of inactivity between activations was set for 30 seconds. Each location had at least one Bushnell camera trap positioned facing the bait (only in one instance was there two camera traps focusing on one bait item, due to the greater size of the bait). Vegetation that would trigger or block the camera was cleared, following an initial vegetation survey.

Camera traps were then set up facing northwards or southwards at a minimum of three metres from the bait, which was measured approximate to three strides. The camera traps used regular SD memory cards, which recorded anything which fed upon or moved near the bait for the entirety of the samples' duration. Camera traps were checked upon every three days and retrieved either when the bait was entirely consumed or had been removed from view of the camera and was unable to be replaced.

No ethics approval was necessary for the study and a prior agreement with Armonia ensured the supply of fresh carrion each week. Other dead animals found to be of at least 50cm in length were used as bait. Any alternate bait types can be found in Table 1 in Appendix I. In total, when larger pigs were divided into smaller sizes, this gave a total of 17 sample sites. Dividing the bait allowed us to increase the number of sample sites and reduced the range in bait size. The bait was secured either using wooden stakes in the ground, or tied to a stake/tree where possible, in order to prevent animals immediately displacing the bait from its site. Staking baits was not possible during placements at night due to safety considerations.

[Analysis](#)

Images recorded by the camera traps over the two months were then analysed by one individual upon return from Bolivia. Two approaches were used for photo analysis as it is difficult to estimate abundance from video.

Firstly the photographs were organised by sample site and then analysed. Each species was identified using field guides and the time and date the individuals was recorded was noted (Emmons and Feer, 1990; Perlo, 2015; Rodríguez Mata, Erize and Rumboll, 2006). The taxonomic classes (bird, reptile, or mammal) were also identified. The presence of all species was recorded on camera, and it was noted if the species was a known scavenger or was seen

to be scavenging. This method follows Huang et al., 2014 whereby if an individual of a species is captured in an image if it is seen again within ten minutes it is not noted. After ten minutes it is assumed to be a different individual. As the camera traps were all out for different lengths of time (ranging from 8.3 hours to 114 hours) the relative abundance was standardised by the shortest 'sample' time (8.3 hours), with 'sample' meaning the entire duration of time that the camera trap recorded images for. Additionally, the maximum number of individuals in a single frame in any one period (MaxN) was also recorded for each period. MaxN underestimates the true abundance of scavengers visiting bait, and the occurrence of separate visits by different individuals of the same species is recorded as 'MaxN', partially visible individuals also count for MaxN. The use of MaxN implies conservative estimates of abundance in high density areas, and so differentiates effectively between areas of high and low abundance (Cappo et al., 2003).

Statistical Analysis

PERMANOVA and PCO habitat community analysis

Multivariate analyses were used to investigate patterns in the spatial distribution of the species across habitat types based on MaxN. Permutational multivariate analysis of variance (PERMANOVA) was used to test for differences and estimate components of variation due to habitat type and side of the reserve (Anderson 2001). To do so the species assemblage data were fourth root transformed to down weight the effect of species' relative abundance and the high frequency of zero counts. I chose to use the Bray-Curtis distance measure to construct a resemblance matrix (Bray and Curtis 1957). This dissimilarity measure was chosen as it is used to indicate species turnover between the assemblages or sample and is therefore an appropriate for this type of ecological data (Faith et al. 1987; Legendre and Gallagher

2001). A principal coordinate analysis (PCO) was used to examine the relationships amongst the samples, based on the species assemblage data (Anderson 2003; Anderson et al. 2008). PCO allows the minimisation of residual variation in any chosen resemblance measure (Anderson et al. 2008). The PCO and PERMANOVA were calculated using PRIMER, with the PERMANOVA done using PRIMER(PERMANOVA) (Primer-e.com, 2017)

Pearson's Chi squared tests were carried out to test if there was a preference for forested or unforested areas (however the taxonomic class 'reptile' was removed due to the sighting of only one reptile) and also to test if there was a difference in relative abundance across the two sides of the reserve. R was also used for the statistical analysis (R Development Core Team, 2008). Generalised linear models (GLMs) were run on the three most abundant scavenging birds, southern crested caracara, black vulture and turkey vulture to determine whether there was a preference of habitat (forested/unforested) and to see if the side of reserve (east/west) affected abundance.

Results

Overall a total of 12 baited sites were recorded, with half on the unranch side of the reserve, and the other half on the ranch side. Photographs were analysed, although for one sample (DCAF1) videos were required due a lack of clarity in photographs. Four habitat types were used in the study; forest, long grass, short grass and riverside (see Table 1, Appendix 1).

I will first discuss PERMANOVA community analysis which has been plotted as a PCO. Secondly, Chi-squared tests on 'Taxonomic class' and then 'Species' were conducted in order to conclude that the relative abundances of scavengers found in certain areas (i.e. forested/unforested and ranch/unranch) were not found due to random chance.

Generalised linear models were ran on three species, black vulture (*C. atratus*), turkey vulture (*C. aura*) and southern crested caracara (*C. plancus*), as they were the most abundant species found in the study and illustrate the different life history strategies that scavengers can utilise.

PERMANOVA results

Overall none of the F-tests produced significant effects and of the three p-values that were produced, although the interaction between side and habitat was significant ($p < 0.05$) (see Table 1). This PERMANOVA result of the whole community on Bray-Curtis dissimilarities shows that habitat and the side of the reserve produced significant results, thus suggesting that the community changes are associated with the interaction between habitat type (forest, river, short grass, long grass) and the side of the reserve (eastern/western).

Table 1: Results of PERMANOVA analysis of the Bray-Curtis dissimilarities for number of individuals of different scavenging species in relation to the side of the Barba Azul reserve they were located and the habitat preference they exhibited. Significant p-values (< 0.05) are shown in bold.

	DF	SS	MS	Pseudo -F	P(perm)
Habitat	3	6562.6	2187.5	1.607	0.163
Side of reserve	1	3654.5	3654.5	2.685	0.056
Habitat x Side of reserve	2	6452.2	3226.1	2.371	0.044
Residuals	3	5443.7	1360.9		
Total	10	23620.0			

A principal coordinate analysis was used to depict prominent patterns and structures in the species assemblage data (Figure 4). A total of 78.9% of the variation in the community assemblage could be explained by the first two PCO axes. PCO1 explained 56.2% of the total variation in the assemblage, whilst PCO2 explained 22.7%. From examination of the graph,

PCO1 was describing the separation of samples along habitat types, while factors structuring PCO2 are describing the side of the reserve. To investigate which species were influencing these changes in the assemblage, the species vectors were overlaid on the PCO. Species vectors represent raw Pearson correlations (at a value of 0.4) calculated for each species with the original PCO axes, excluding all other species, so may be only used as a guide (Anderson et al. 2008). The PCO indicates that the distribution of species varied between habitats, supporting the PERMANOVA results; for example the turkey vulture (*C. aura*) being mainly distributed in the forest.

Chi-Squared tests; distribution in habitat and side of reserve.

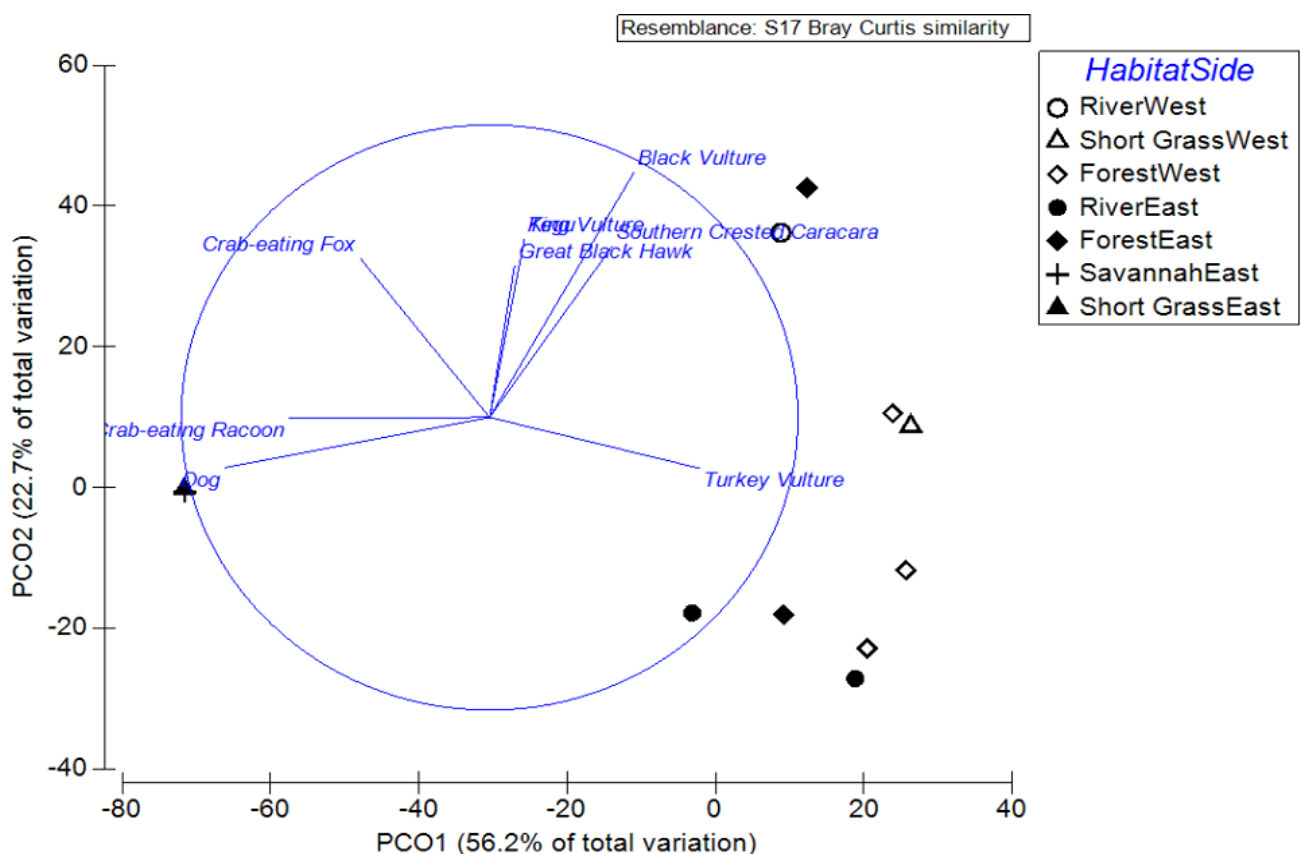


Figure 4. Principal coordinate analysis (PCO) of the habitat assemblage overlaid with nine of the significant species vectors (the raw Pearson correlations). The length and direction of the vectors represent the strength and direction of the relationship.

One of the questions that needed addressing in the study was whether the birds and mammals showed a preference for habitat; divided into 'forested' and 'unforested' areas the data was then subject to a Chi squared test that was carried out and a significant result was produced ($X^2 = 61.312$, $DF=1$, $p\text{-value} = <0.01$) and the null hypothesis that mammals and birds would show no preference for forested habitats can therefore be rejected. Forested areas are the preferred habitat of birds, shown by the 1083 individual birds that were recorded in forests (compared to the 188 in unforested) whereas unforested areas were preferred by mammals; with 12 recorded in forested areas and almost double in unforested areas (see Table 2) .

Table 2: Total number of individuals for each taxonomic class recorded in forested areas and the unforested areas

<u>Taxonomic Class</u>	<u>Number in Forested</u>	<u>Number in Unforested</u>	<u>Total</u>
Bird	1083	188	1271
Mammal	12	23	35
Total	1095	211	1306

Similarly the preference for which side of reserve the species were recorded on was also tested using a second Chi squared test that was carried out using R and a significant result was produced ($X^2 = 27.742$, $DF=12$, $P\text{ value} = <0.01$). The null hypothesis that the relative abundance of species would be equal in both sides of the reserve can be rejected, thus showing that the eastern side (ranch) had a greater relative abundance than the unranch western side, as 757 total animals were recorded in the eastern side, and 549 in the western side (see Table 3).

Table 3. The species composition and the number of individuals of scavengers recorded in the eastern side of the reserve and the in the western side.

<u>Species</u>	<u>Number in eastern side (ranch)</u>	<u>Number in western side (unranch)</u>	<u>Total</u>
Black Crowned Night Heron	1	0	1
Black Vulture	448	321	769
Cocoi Heron	1	0	1
Collared Peccary	0	7	7
Crab-eating Fox	19	3	22
Crab-eating Raccoon	1	0	1
Dog	5	0	5
Great Black Hawk	0	1	1
King Vulture	1	0	1
Lesser Yellow-headed Vulture	0	3	3
Southern Crested Caracara	186	146	332
Turkey Vulture	95	68	163
Total	757	549	1306

Figure 5 shows a bar chart displaying species (organised by taxonomic class: 'Mammal' and 'Bird') and of the individuals that were recorded, what percentage of those species were recorded in the eastern or western side of the reserve. A total of 12 scavenging species were recorded, four mammals and eight bird species. Total numbers seen can be seen on the right of the chart; only four species were recorded on both sides of the reserve. Interestingly five of the species were only noted in the eastern side, and two only in the west, although it is important to note that five of the species were only recorded once: great black hawk (*Buteogallus urubitinga*), black crowned night heron (*Nycticorax nycticorax*), king vulture (*S. papa*), cocoi heron (*Ardea cocoi*) and crab-eating raccoon (*Procyon cancrivorus*).

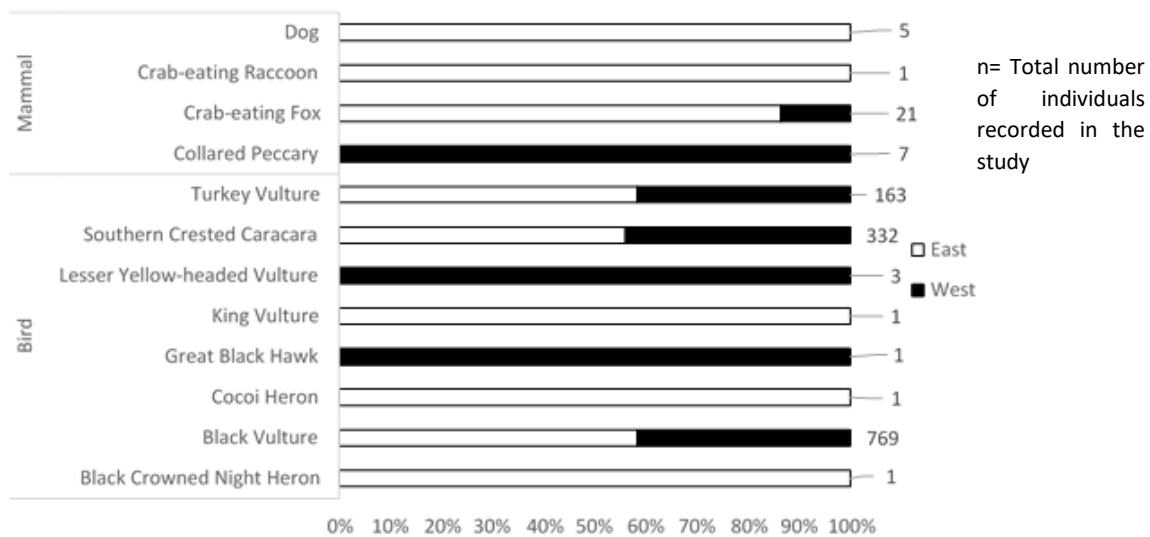


Figure 5. A bar chart showing the abundance of species in terms of percentages (organised by taxonomic class numbers indicate relative abundance) recorded in the different sides of the reserve.

Figure 6 shows a bar chart displaying species (organised by taxonomic class, mammal or bird) and of the individuals that were recorded, what percentage were recorded in forested or unforested areas. A total of 12 scavenging species were recorded, four mammals and eight bird species. Of the mammals, only collared peccary (*Pecari tajacu*) were exclusively recorded in the forest, whilst dogs (*Canis familiaris*) and crab-eating raccoons (*P. cancrivorus*) were found exclusively in unforested; only crab-eating foxes (*C. thous*) were recorded in both forested and unforested areas.

[Generalised Linear Models; habitat preference of abundant species](#)

The most abundant bird in the study was the black vulture, and so generalised linear models were used to see if relative abundance was affected by the habitat (forested/unforested) and to see if abundance was affected by reserve side (ranch= east, unranch= west) (see Figure 8). In the case of black vultures, both results were significant, significant p values are in bold

in Table 4 (DF=187, $p = <0.01$). This therefore shows that both habitat type and side of the reserve affected relative abundance, see Figure 7.

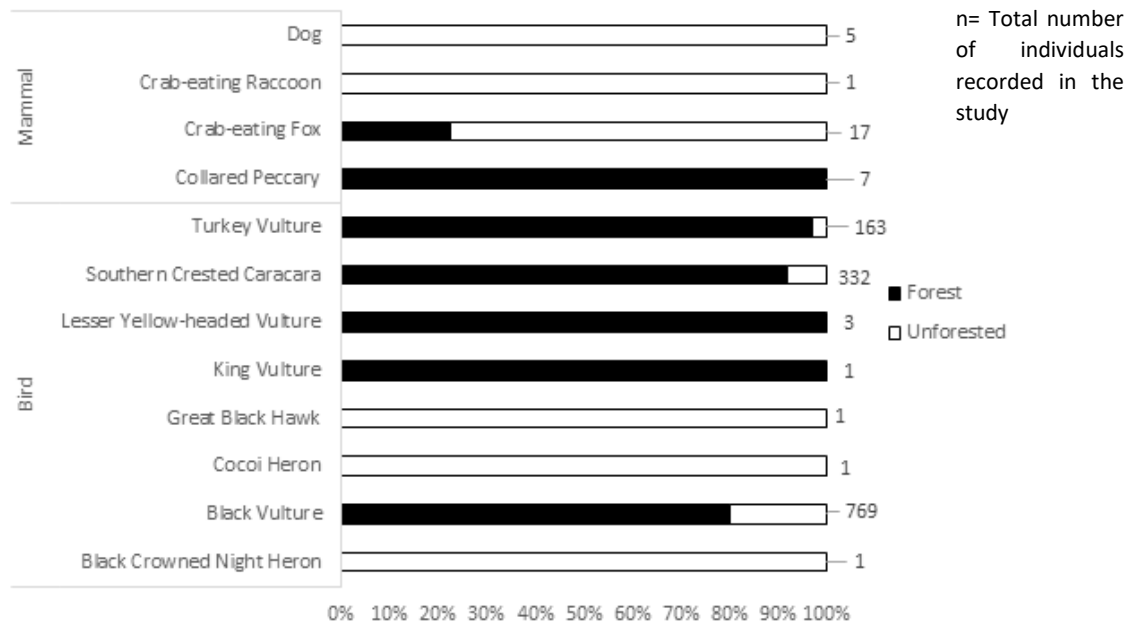


Figure 6. A bar chart showing the abundance of species in terms of percentages (organised by taxonomic class, numbers represent relative abundance) recorded in forested and unforested areas.

Table 4. Table showing the results from the generalised linear model running standardised numbers of black vulture as a capacity of habitat type and reserve side

	Estimate	Std Error	z-value	p-value
(Intercept)	-1.3583	0.1963	-6.918	<0.005
Forest/Unforested	1.1092	0.1971	5.628	<0.005
Side of Reserve	0.6432	0.2168	2.967	<0.005

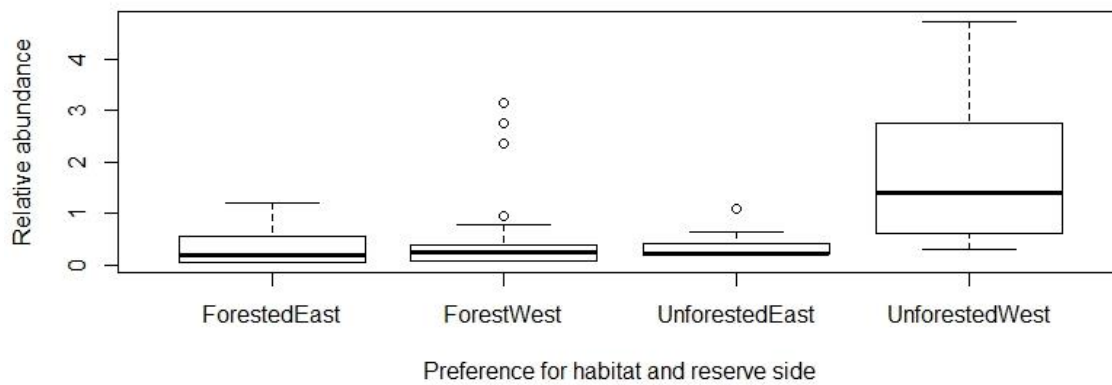


Figure 7. Figure 7 shows a boxplot showing the relative abundance of black vultures in forested or unforested areas, with respect to which side of the Barba Azul Reserve they were recorded on.

Generalised linear models were also used in respect to turkey vultures, in order to see if relative abundance was affected by the habitat (forested/unforested) and to see if abundance was affected by reserve side (ranch= east, unranch= west), see Figure 8, in this instance there was no significant effect, showing that habitat type and ranching had no effect in this study, see Table 5.

Table 5. Table showing the results from the generalised linear model running standardised numbers of turkey vulture (*C. aura*) as a capacity of habitat type and reserve side

	Estimate	Std Error	z-value	p-value
(Intercept)	-1.3583	0.1963	-6.918	<0.005
Forest/Unforested	1.1092	0.1971	5.628	0.433
Side of Reserve	0.6432	0.2168	2.967	0.423

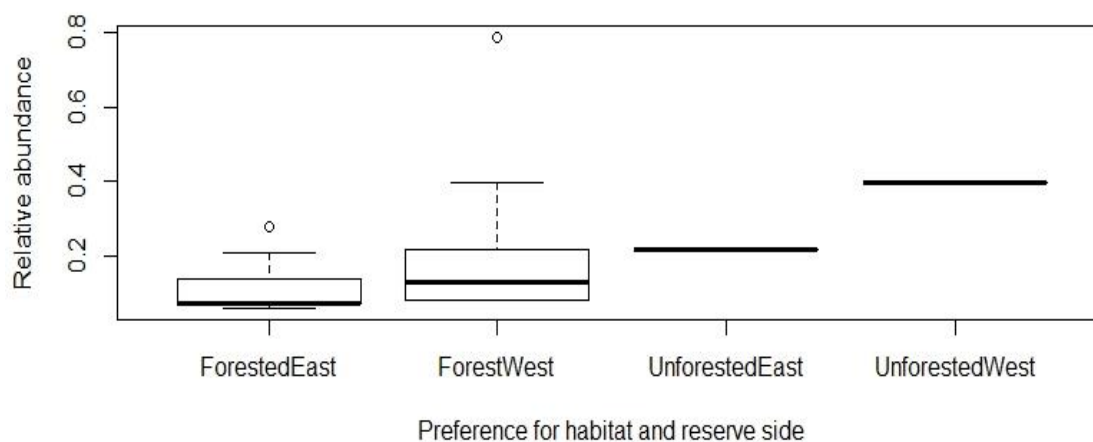


Figure 8. Figure 8 shows a boxplot showing the relative abundance of turkey vultures in forested or unforested areas, with respect to which side of the Barba Azul Reserve they were recorded on.

Generalised linear models were then used to see if relative abundance was affected by the habitat (forested/unforested) and to see if abundance was affected by reserve side (ranch= east, unranch= west) in southern crested caracara, demonstrated in Figure 9. Similarly to turkey vultures, there was no significant effect produced concerning either factor, see Table 6.

Table 6. Table showing the results from the generalised linear model running standardised numbers of southern crested caracara (*C. plancus*) as a capacity of habitat type and reserve side

	Estimate	Std Error	z-value	p-value
(Intercept)	-1.3583	0.1963	-6.918	<0.05
Forest/Unforested	1.1092	0.1971	5.628	0.106
Side of Reserve	0.6432	0.2168	2.967	0.522

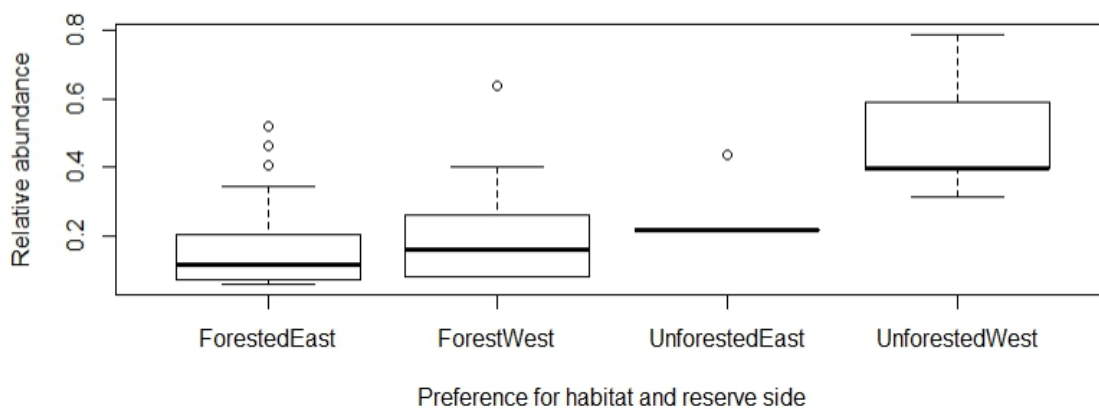


Figure 9. Figure 9 shows a boxplot showing the relative abundance of southern crested caracara in forested or unforested areas, with respect to which side of the Barba Azul Reserve they were recorded on.

Discussion

It is well documented in certain areas that habitat type and complexity can have a range of impacts on community assemblage, the complexity of the role that scavengers play has meant that there is less research in this area than others (Friedlander and Parrish, 1998; Lassau and Hochuli, 2004). The PERMANOVA results (see Table 1) showed that changes in the community assemblages were associated with the interaction between habitat type (forest, river, short grass, and long grass) and the side of the reserve (eastern/western). This demonstrates the complexity and interconnectivity of scavenging communities, as different species have

different impacts on the facilitation or limitation of scavenging in different habitats. The different levels of grazing pressure on the reserve may also have impacts on the habitat types themselves, for instance it is known that grazing cattle take refuge in forests overnight. As they do this they consume regenerating plants and compact the soil (Boorsma, 2016). Figure 4 shows the PCO that was plotted and whilst PCO analysis does not identify what factors are structuring the difference in community assemblies, it does show us how the different species recorded were influencing the changes. For instance three mammal species, crab-eating fox (*C. thous*), crab-eating raccoon (*P. cancrivorus*) and dogs (*C. familiaris*) are shown on the PCO between -40% and -70% on PCO1. Although the species vectors represent raw Pearson correlations and may be only used as a guide, the presence of dogs may have affected the study; the dogs belonged to the ranch and so were an *unavoidable* part of the study. (Anderson et al. 2008).

The Chi-squared tests performed show clear differences between the two taxonomic classes in the study. The first chi-squared test (see Table 2) showed a greater abundance of birds in forested areas (1083 individual birds in forests compared to the 188 in unforested) whereas unforested areas held a greater abundance of mammals; with 12 recorded in forested areas and 23 in unforested areas. This has certain implications concerning deforestation and forest degradation; as these factors are well documented in terms to their relation to biodiversity loss (Brooks et al. 2002). As such, while not under threat of deforestation, the forest islands in the Barba Azul reserve have been under considerable pressure over the years from cattle grazing; a recent measure by Armonia is to fence off certain forest islands to protect them from cattle and feral pigs, yet still allow endemic mammals to enter. This could have both positive and negative effects on scavengers. Firstly the prevention of grazing in the forest islands should in turn promote regeneration of certain species such as Motacu palm trees

(*Attalea phalerata*). The regeneration of forest floor growth in turn could increase the populations of small rodents and reptiles which in turn leads to an increase in the species diversity of raptors (many of which are scavengers) and also means that species such as the southern crested caracara (*C. plancus*) will potentially rely less on carrion, meaning a greater food resource for vultures (Carrete et al., 2009). The prohibition of cattle entering the forest islands also means that any deaths will occur in unforested areas. This could then be beneficial for mammals as it will be easier for them to find carrion in their large territories. In summary the ecological consequence of changing the land-use management of the forests in the reserve may have several knock on effects that can only be recorded with future studies. Deforestation as a cause for the loss of biodiversity is well known, but this reiterates the importance of arboreal systems as this result shows the importance of arboreal areas in terms of ecosystem function, as they facilitate the feeding of vital bird scavenging species; which in the Barba Azul reserve are the dominant (in terms of abundance) taxonomic class of scavengers.

Some New World Vultures are known to be forest-dwellers, but the degree of which is not known. It may be that the large ranges and adaptability of the vultures must allow for a certain degree of flexibility that changes foraging habits depending on geography. The preference of unforested areas by mammals is interesting, however the reasoning for this preference is unclear. It may be that mammals struggle to search the forest floor for carrion, but in unforested areas the carrion has a greater visibility from a distance, and potentially the lack of trees allows for scents to be carried greater distances. The preference of unforested areas could also mean that the mammals are at greater threat from the burning of grasses for pasture land conversion.

The significant result of the second Chi-squared test, which showed a greater species abundance in the eastern (ranch) side of the reserve is of particular interest, as an intense grazing pressure is well known to be negative for biodiversity. Some studies have found that the presence of cattle increases the populations of certain raptors and decreases others, with the likelihood of finding king vultures (*Sarcoramphus papa*) increasing linearly with increasing cattle populations. As only one king vulture was recorded, the lack of replicates limits the result, but it is of interest that it was recorded in the eastern side of the reserve where the grazing pressure is greater. A study in Peru in a neotropical rainforest reserve found that most raptor species tolerate cattle densities between 20-60 cattle per km². However after increases above 60 cattle per km² many rarer raptors decline, including the great black hawk (*B. urubitinga*), a species that is more associated to forests, this species was found to decline at densities of over 60 cattle km² (GRIN, 2012; Piana and Marsden, 2014). Although numerous raptor species are found in the Barba Azul reserve, including Swainson's hawk (*Buteo swainsoni*), only two raptors excluding the vultures were recorded; the southern crested caracara (*C. plancus*) which was found in great abundance and the great black hawk (*B. urubitinga*). Whilst only one great black hawk (*B. urubitinga*) was recorded in the study, it is interesting to note it was recorded in the unranch side of the reserve which supports the idea that they are absent in areas with high densities of cattle. Further studies into densities of cattle would allow a greater understanding of the linear relationship between scavengers and grazing pressures in the Beni. The limitations of single individuals with no replicates (such as with the king vulture and the great black hawk) shows the necessity for long-term scavenging studies to ensure rarer species of scavenger are accounted for. There are potentially other reasons for the greater species diversity and abundance in the ranch side of the reserve, in the context of scavenging. The timing of the study coincided with the

calving season of the cattle and a high infant mortality rate along with other products from birth (such as the afterbirth) may have attracted scavengers to the area, as this may be a food source for scavengers. There is evidence of black vultures consuming the afterbirth of capybara (*Hydrochoerus hydrochaeris*) however the extent to which scavengers consume cattle afterbirth is unknown (ARKive, 2017). There is therefore a potential for a further study investigating the temporal differences in abundance of scavengers, looking at how calving season affects the relative abundance; if during calving season there is a higher relative abundance then it is of interest to determine where the scavengers reside at other times. If time of year has no effect on scavenger populations, and ranches naturally attract scavengers due to the high density of large herbivorous mammals, then there are interesting conservation implications as ranches could become important areas to study scavengers and their effect on ecosystem function. Additionally studies of vultures at ranches may indicate the importance of their role in the ecosystem and the knock-on effects that the extinction of certain vulture species may cause.

The generalised linear models (GLM) ran on turkey vultures (*C. aura*) and southern crested caracara (*C. plancus*) data showed no significance for habitat, however there are studies that show that turkey vultures are predominantly forest dwelling vultures (Houston, 1994). Whilst the two second most abundant birds showed no significant preference for habitat or side, their abundance may change seasonally. It is known that the number of individuals of the turkey vulture (*C. aura*) fluctuates greatly throughout the year in areas of Uruguay and Brazil due to seasonal migrations (Zilio, Verrastro and Borges-Martins, 2014). The black vulture (*C. atratus*) however was recorded in abundance, and the GLM's showed significance for both habitat and side of the reserve; in essence black vultures show preference for ranches and forested habitat. The preference for forested areas is documented, however increasingly

black vultures are favouring urban environments; although it has been found that turkey vultures will actively avoid urban habitats if black vultures are present (Coleman and Fraser, 1989; Novaes and Cintra, 2015). This interspecific avoidance may support the differences shown between the black vulture and turkey vulture shown the PCO, as they differed greatly on the PCO₂ axis. This also reflects the importance of community assemblies relating to habitat as it explains that the presence of black vultures may negatively impact the presence of turkey vultures.

Vertebrate scavengers and invertebrate decomposers compete for animal carcasses in all temperate and tropical ecosystems and insects play a significant role in decomposing and consuming carrion (DeVault, Brisbin, Jr. and Rhodes, Jr., 2004). During the study there were a number of species that would frequent the bait, such as cockroaches, mosquitoes, pallo diablo ants and beetles (Personal Observation, 2016). The studying of insects as scavengers would allow for more replicates also, as bait size could be much smaller. The samples could also be collected and would allow for a more precise estimate of relative abundance. Past studies on insects have found that the composition of insect scavenger assemblies has direct effects on the ecosystem process, and a positive relationship between biodiversity and the speed to which carrion is removed was also recognised (Farwig et al., 2014). In the context of the Beni Department little is known about the entomological side of scavenging and what role this plays in the ecosystem.

Despite their lack of presence in this study, large mammals are of significance when discussing the ecology of scavenging. Pumas (*Puma concolor*) are known to be important sources of food through carcass abandonment (Wilmer et al., 2003). The lack of large mammals in this study has interesting connotations as these large predators influence the structure and composition

of scavenger communities in different ways. Puma for example, are apex predators and occasionally scavenge as part of their diet whilst also facilitating the consumption of carrion by other scavengers. Whereas in North America, dominant scavengers, such as black bears (*Ursus americanus*), are known to limit other scavengers, and when present at a carcass reduce the total species richness (Allen et al., 2014). Future studies in the Beni between the interactions between large carnivores and scavengers would be valuable, as evaluating the role of jaguars (*Panthera onca*) and pumas (*Puma concolor*) would allow us to learn more about the food webs and ecological communities of the Beni Department.

Overall the study has found that localised ranching has a positive correlation with species diversity and abundance; although longer term studies need to be conducted into the temporal fluctuations concerned with the calving season of cattle. The dominant scavenging taxonomic class in the Barba Azul Reserve was birds, with black vulture, turkey vulture and southern crested caracara being the most abundant species. Scavenging birds had greater relative abundance in forests and showed a habitat preference for forested areas. Mammals showed a preference for unforested areas, however only small scavenging mammals were recorded, including collared peccary (*Pecari tajacu*), which are not known to scavenge often and is rare behaviour captured in this study. The role that vultures and other scavengers play is of paramount importance in an ecological sense. Future studies on habitat preference and the effects that habitat loss and habitat degradation have on ecosystem function and scavengers are crucial.

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[Development of the project](#)

The development of the project began prior to the University of Glasgow's Bolivia Expedition 2016 in June. The execution of the project remained very similar to the original plan. I had visited the Barba Azul reserve in 2014 and knew the background of the biodiversity there, including that there were healthy populations of vultures. So in the summer of 2016 I visited the Barba Azul Reserve for two months and used baited camera traps in a number of habitats to record any organisms that scavenged upon it.

Whilst in Bolivia I learned that the reserve was still separated by a border fence as the eastern side of the reserve was being sustainably ranching as part of a project Armonia are conducting. The plan then developed to test the differences between the reserve sides to study the impacts of ranching on scavenger ecology.

Whilst the method used remained very similar to the initial method, issues in the field, such as a limited number of available AA batteries for the Bushnell camera traps and a smaller amount of available bait meant that the number of camera traps used was fewer than originally anticipated, it was ensured that enough were still used to collect sufficient data for the project.

[Appendix I](#)

Table 1: A table showing all bait site information, bold indicates the camera traps actually use in the study, many of the camera traps were placed out and bait was removed immediately, or the camera trap failed to trigger.

<u>Site</u>	<u>Date</u>	<u>Time</u>	<u>GPS</u>	<u>Bait type used</u>
DPF1	03.07.16	11:32	S 13 45.617' W 066 06.627'	Pig
DCAF1	04.07.16	13:21	S 13 45.622' W 066 06.627'	Calf
DCWF1	14.07.16	07:22	S 13 45.652' W 066 07.714'	Cow
DPR1	5.07.16	17:15	S 13 45.702' W 066 06.627'	River
DPR2	29.07.16	11:34	S 13 45.675' W 066 07.119'	River
DPEF1	22.07.16	09:32	S 13 45.746' W 066 05.903'	Peccary (juvenile)
DPSG1	17.07.16	14:35	S 13 45.487' W 066 07.206'	Pig
DPLG1	17.07.16	14:10	S 13 45.650' W 066 07.174'	Pig
SACAF1	16.08.16	18:00	S 13 44.447' W 066 02.593'	Calf
SAPR1	17.08.16	19:45	S 13 44.944' W 066 04.355'	Pig
SAPR2	30.08.16	09:10	S 13 45.120' W 066 02.445'	Pig
SAPF1	17.08.16	20:00	S 13 44.962' W 066 03.926'	Pig
SAPF2	30.08.16	09:15	S 13 45.036' W 066 02.502'	Pig
SAPSG1	17.08.16	20:15	S 13 44.655' W 066 04.162'	Pig
SAPSG2	26.08.16	20:46	S 13 44.791' W 066 02.400'	Pig
SAPLG1	26.08.16	20:26	S 13 44.883' W 066 02.445'	Pig
SAPLG2	21.08.16	15:30	S 13 44.944' W 066 03.355'	Pig

[Additional data collection](#)

A vegetation survey was also carried out at each site also, measuring the leaf litter (% cover), canopy cover (%), maximum vegetation height (mm) and average vegetation height (mm). To carry out the survey, a 50x50cm quadrat was randomly placed within a close vicinity (200cm) of the bait. Percentage coverage for leaf litter and canopy cover was estimated, calibrating

before the survey by studying differently pieces of paper, each of which had a percentage of the squares shaded in upon it. (0%, 25%, 50%, 75%, 100%).

Copies of the datasheets have been submitted on an SD card with the physical copy of the study along with the progress book used whilst in country conducting the fieldwork.