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Jaguar (*Panthera onca*) and puma (*Puma concolor*) hunting preferences, and their effect on cattle (*Bos taurus*), in Pantanal, Brazil

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Jaguarers (Panthera once) och pumors (Puma concolor) jaktpreferenser, och dess påverkan på boskap (Bos taurus), i Pantanal, Brazil

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Abstract

In Brazil, jaguars and pumas both constitute threats to cattle farming due to predation on calves. Since both jaguar and puma populations decline, conflicts with humans should be avoided in order to prevent poaching, which can lead to the number of wild cats in Brazil decreasing further. The aim of this study was to identify in which environments attacks on cattle mainly occur and whether some groups of cattle are more affected than others. With such knowledge, more effective countermeasures might be deployed in order to prevent attacks, leading to better coexistence. During 2017 and 2018, two farms affected by predation were visited. With the assistance of the ranchers, the sites for attacks were analysed with regard to vegetation types, date, moon phase and traits of the calves. The positions of carcasses were documented with GPS acquired from a mobile phone. Age, breed and sex of the killed animals were also documented. The species of the predator was established by the ranchers based on the type of damage endured by the carcass, footprints and if it had been covered by foliage. The geographical positions of the attack sites were analysed using ArcGIS. Predated calves were up to one year old, only one calf was older, The age group consisting of calves of 180-270 days was more affected than expected at the farm Sao Bento, as few animals in that age range were present on the farm. Pumas took much younger prey than jaguars. Both pumas and jaguars hunted at one of the farms while the other farm only experienced puma attacks. Overall, more attacks occurred in open vegetation than close to or in forests. However, both farms disproportionally consist of open vegetation, and hence forests still seem to be important for jaguars and pumas while hunting. There were a number of attacks recorded within 100 m of houses and roads. Moon phase affected predation; there was a higher risk of killing prey at new moon or close to it. Most of the attacks occurred during the dry season, which is probably a result of farm routines rather than an environment effect. No single obvious strategy for protecting livestock can be derived from the findings of this study. In order to develop better predation prevention strategies at farms, it is important to know which cattle that are risk groups and under which circumstances. There is thus a need for further studies in the research area, as little seems to be known about how, for example, cattle and predators are affected by moon phase.

Keywords: Panthera onca, Puma concolor, Bos taurus, Bos indicus, Pantanal, Brazil.

Sammanfattning

I Brasilien betraktas jaguarer och pumor som ett hot mot boskapsuppfödningen då de kan döda boskap. Både jaguarer och pumor har minskat i antal. Tjuvjakt kan leda till att antalet vilda kattdjur i Brasilien minskar ännu mera, det är därför viktigt att motverka konflikter mellan människor och vilda katter. Syftet med denna undersökning var att identifiera i vilka miljöer jakt på boskap huvudsakligen uppstår och om vissa grupper av boskap påverkas mer än andra. Med den kunskapen kan effektivare åtgärder kanske vidtas för att förhindra attacker, vilket kan leda till bättre samexistens. Under 2017- 2018 besöktes två gårdar. Med hjälp av boskapsskötare analyserades attacker på boskap med avseende på vegetation, månfas och kalvens egenskaper såsom ålder, ras och kön. Positionerna där boskap hittats dödade bestämdes med GPS i en mobiltelefon. De dödade djurens ålder och kön bestämdes utifrån uppgifter från gårdarna. Med hjälp av boskapsskötare och baserat på skador på kadavret, tassavtryck och om kadavret var täckt med buskage bedömdes det om predatorn var en jaguar eller en puma. Attackernas geografiska positioner har sedan analyserats med ArcGIS. Kalvarnas som dödats var upp till ett år gamla, endast en kalv var äldre. Åldersgruppen 180–270 dagar drabbades mer än förväntat på gården Sao Bento då många boskap i den åldersgruppen sålts och det därför fanns relativt få djur i den åldersgruppen på gården. Pumor tog mycket yngre boskap än jaguarer. Både pumor och jaguarer jagade på en av gårdarna medan den andra gården bara hade pumaattacker. Fler attacker förekom i öppen vegetation än vid skogsområden. Dock bestod bägge gårdarna till största delen av öppen vegetation. I det sammanhanget skedde relativt många attacker ändå vid skogskanter vilket tolkades som att skogsområden ändå verkar vara viktiga för jaguarer och pumpor när de jagar. Det förekom attacker inom 100 m från hus och vägar. Månens faser påverkade antalet attacker; det var högre risk för boskap att dödas vid nymåne. De flesta attackerna inträffade under torrperioden. Det är troligen ett resultat av gårdsrutiner snarare än en miljöeffekt. Utifrån den här studien identifierades ingen uppenbar strategi för att skydda boskap mot predatorattacker. För att utveckla strategier på gårdarna är det viktigt att veta vilka boskap som är riskgrupper och under vilka omständigheter. Det verkar finnas ett behov av fler studier på området då lite verkar vara känt om hur till exempel boskap och predatorer påverkas av olika månfaser.

Nyckelord: Panthera onca, Puma concolor, Bos taurus, Bos indicus, Pantanal, Brazil.

Populärvetenskaplig sammanfattning

Både jaguarer och pumor har viktiga funktioner som predatorer inom ekosystem. Samtidigt har båda arterna minskat i antal. Det beror delvis på att deras livsmiljöer förändrats med bland annat avverkad skog. Ytterligare en riskfaktor är konflikter med människor. Konflikter mellan människor och vilda rovdjur är ett globalt problem. I Sverige uppstår det till exempel konflikt mellan fårbönder och vargar. I Brasilien är framförallt jaguarer och pumor ett hot mot boskapsuppfödning. I tidigare studier har forskare undersökt brasilianska bönders inställning till jaguarer och pumor och funnit att många har haft negativa attityder mot stora kattdjur. En risk med konflikter mellan människor och vilda djur är att tjuvjakt kan öka. Detta kan leda till att sårbara rovdjur blir ännu mer sällsynta med negativa effekter på ekosystem som en följd. För att skapa en bättre samexistens mellan människor och stora kattdjur är det viktigt med kunskap om kattdjurens jaktbeteenden. Kunskapen kan användas för att skydda tamdjuren och få bönder att känna sig mindre hotade av jaguarer och pumor. Det är även viktigt att förstå vilken jaktmiljö jaguarer och pumor behöver för att jaga effektivt i det vilda. Detta då det finns misstankar om att de dödar mer boskap som ett resultat av minskad tillgång till naturliga byten och bra jaktmiljöer.

I tidigare studier har man sett att vilda kattdjurs jaktbeteenden påverkas av vegetationstyper. Både jaguarer och pumor har i tidigare studier verkat föredra att jaga vid skogskanter. Det finns teorier om att de lättare uppfattar bytet när det rör sig vid skogskant samtidigt som de själva kan hålla sig gömda. Tidigare studier har också visat att vilda djur kan anpassa sin dygnsrytm efter hur starkt månskenet är som en jaktstrategi. Det är ett samspel mellan hur bra mörkerseende bytesdjuret har i förhållande till predatorn. Intressanta miljöfaktorer som kan påverka jaguarers och pumors jaktpreferenser kan därför vara vegetation, månljus och även säsong.

För att kunna vidta mer effektiva skyddsåtgärder är det även intressant att undersöka om vissa boskapsgrupper har en högre risk att dödas än andra. Faktorer som skulle kunna ha en betydelse är ålder, ras och kön. Ras kan vara av betydelse då modersinstinkten och flyktinstinkten kan skilja mellan raser. Vissa studier har funnit att tjurkalvar har en högre risk att bli dödade av rovdjur. Varför vet man inte riktigt.

Den insamlade datan indikerar att attacker sker i många typer av vegetationer men i förhållande till andelen skog skedde en stor del av attackerna i skogskanter. Flest attacker inträffade under torrsäsongen. Flest attacker skedde vid nymåne. Boskap dödades upp till drygt ett års ålder. Två utsatta åldersspann var 0- 90 och 180- 270 dagars ålder vilket indikerar att unga och nyligen avvanda djur är utsatta. Tjurkalvar verkar dödas oftare än kvigkalvar i förhållande till antal djur av olika kön som fanns på gårdarna.

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1 Introduction

1.1 Human- wildlife conflict

Human- wildlife conflict is a problem for the conservation of wild animals. One possible source of conflict is predation on livestock by one or more species of predators. For example, Oli *et al.* (1994) and Lenihan (1996) found negative attitudes towards snow leopards (*Panthera uncia*) and wolves (*Canis lupus*), respectively, caused by predation on cattle.

Predation on livestock is a global problem and has been reported from several continents. For example, studies by Patterson *et al.* (2004), Woodroffe *et al.* (2005) and Kolowski and Holekamp (2006) report predation on livestock caused by wild animals in Africa, where predators such as lions (*Panthera leo*), cheetahs (*Acinonyx jubatus*), spotted hyenas (*Crocuta crocuta*), leopards (*Panthera pardus*) and African wild dogs (*Lycaon pictus*) have been observed to hunt cattle. From Asia, previous studies describe snow leopards as a threat to cattle. Snow leopards are known to kill cattle in Nepal (Oli *et al.,* 1994), as well as in Ladakh, Tibet and Mongolia (Jackson & Wangchuk, 2001).

Livestock predation by jaguars or pumas has been noted in, among other locations, Belize (Rabinowitz, 1986), Venezuela (Hoogesteijn *et al.,* 1993; Polisar *et al.,* 2003) and Brazil (Mazzolli *et al.,* 2002; Conforti & Azevedo, 2003; Zimmermann *et al.,* 2005; Michalski *et al.,* 2006; Palmeira & Barrella, 2007).

Still, few studies have been able to show significant economic impact caused by the predation on cattle (Michalski *et al.,* 2006; Palmeira & Barrella, 2007). For example, Patterson *et al.* (2004) found that 2.4% of the livestock population was killed by wild animals during one year in Kenya. However, the local history of attacks has been shown to negatively affect cattle owners' perception of the predator species (Soto-Shoender & Main, 2013). Due to this effect, a limited number of attacks could plausibly constitute sufficient grounds for farmers to adopt a negative attitude towards the

predator species, which in turn could lead to poaching. As a result, threatened predators might in fact become even more vulnerable.

1.2 Human-wildlife conflict in Brazil

In Brazil, economic consequences of predation on livestock have generally been considered modest. Michalski *et al.* (2006) reported that 1.2% of the livestock was killed annually by wild animals in the Amazon, which in the bigger picture can be considered low. In the Pantanal and Cerrado regions, the corresponding numbers have been estimated at 0.5% and 0.4%, respectively (Azevedo & Murray, 2007; Palmeira *et al.,* 2008). Regardless, many farmers perceive big cats as a threat to their operation. According to a study by Zimmermann *et al.* (2005), 82% of farmers in northern Pantanal thought jaguars were a threat to cattle and 64% did not accept jaguars on their farms.

Conflicts between humans and big cats exist in the Atlantic forest as well as in the Amazon and Pantanal (Engel *et al.,* 2017). However, the conflict is arguably more pronounced in Pantanal and the Amazon, where the population densities of big cats are higher and, consequently, predation on livestock is more common (Zimmermann *et al.,* 2005; Marchini & Macdonald, 2012).

It is important to note that there are other predators in Pantanal, in addition to the jaguar and the puma, which could plausibly be the cause of livestock demise. This fact is of particular interest in the light of previous studies, which have shown a tendency among farmers to, possibly incorrectly, blame jaguars and pumas in cases when the carcass of the prey is not found (Palmeira & Barrella, 2007; Rosas-Rosas *et al*., 2008). According to intervied farmers predation on calves by vulture is possible. Vulture attacks can lead to death of new-born calves but this is rare (Toledo *et al*., 2013). Poisonous snakes such as *Bothrops mattogrossensis, Bothrops moojeni* and *Crotalus durissus* reside in the area (WHO, 2019), obstructing efforts to determine causes of death. I have not found any study on cattle being killed by a caiman (*Caimaninae*).

1.3 Predators

1.3.1 Jaguars

At the time of writing, jaguars are classified as a near-threatened species by the IUCN (2019). Historically, the species occurred from the south-western United States to the Rio Negro region in Argentina (Engel, 2016). Today,

jaguars are absent from 54% of their original home ranges (Macdonald *et al.,* 2012). In west-central Brazil, the Pantanal region has been considered as a critical area for conservation efforts (Sanderson *et al*., 2002; Bernal-Escobar *et al*., 2015).

Jaguars have a compact body with strong but comparatively short legs (Oliveira & Cassaro, 2005) and typically weighs between 31 and 121 kg (NE, 2020). The fur is primarily coloured yellow, with black spots forming rosettes on their heads, backs, legs and tails (Reis *et al.,* 2006). Their colour deviates ventrally, with white fur covering the chest and abdomen area (Reis *et al.,* 2006). Attacks by jaguars can usually be identified by the carcass of the prey having one or more broken cervical vertebrae (Palmeira *et al.,* 2008). The cause of fracture can be derived from either the animal's fall to the ground or from bites on the skull or on the neck (Palmeira *et al.,* 2008). Jaguars usually start eating the prey from the anterior side, which frequently leaves the posterior parts intact (Schaller & Crawshaw, 1980; Mondolfi & Hoogesteijn, 1986; Hoogesteijn *et al.,* 1993).

In Brazil, the wild prey base of jaguars generally consists of medium to large-sized vertebrates (Engel, 2016). For example, South American tapir (*Tapirus terrestris*), capybara (*Hydrochoerus hydrochaeris*), collared peccary (*Pecari tajacu*), feral European wild boar (*Sus scrofa*) and deer species (*Mazama sp* and others) are all to some extent preyed upon by the jaguar. Jaguars are also known to occasionally consume caiman (*Caiman yacare*) (Perilli *et al.,* 2016).

Jaguars are solitary, nocturnal and territorial animals (Macdonald *et al.,* 2012). Their home range can cover areas of up to ~150 km^2 in size (smaller for females) (Macdonald *et al.,* 2012). Jaguars prefer moving either in dense cover or in adjacency to dense cover (Gese *et al.,* 2018). They seem to select for dense cover when killing cattle in the dry season or native prey in the wet season (Gese *et al.,* 2018). In addition, jaguars seem to prefer killing prey close to water, even in cases when the incidence of water in the landscape (Gese *et al.,* 2018) is limited. Studies have indicated that jaguars cannot compensate for a loss of large-sized prey by eating larger amounts of medium-sized prey (Gonzalez & Miller, 2002; Novack *et al.,* 2005). A tentative explanation for this fact is that a large-sized prey lasts longer whereas, in contrast, the jaguar must most likely search for additional prey immediately after eating a smaller-sized prey, which implies more effort for the same amount of food (Novack *et al.,* 2005). Consequently, when the availability of large prey is reduced, energetic costs may increase (Novack *et al.,* 2005). This may motivate a jaguar to hunt cattle in an environment where there is limited availability of large-sized natural prey.

1.3.2 Pumas

Pumas can be found throughout the region of land delimited by southern Yukon in the north, Tierra del Fuego in the south, the Pacific in the west and the Atlantic in the east (Engel, 2016). Iriarte *et al.* (1990) describe the puma as one of the most adaptable mammalian carnivores. Pumas could in the past be found in the eastern parts of the USA and Canada but vanished from these areas sometime during the last century (Macdonald *et al.,* 2012). Today, pumas have disappeared completely from 27 % of their original home ranges (Engel, 2016). The main threats to pumas as of today are habitat loss and associated conflict with humans (Reis *et al.,* 2006). Pumas are listed as Least Concern by IUCN (2019) but were classified as Vulnerable in Brazil in 2005 (Machado *et al.,* 2005).

The body size of the puma varies greatly depending on the geographical zone in which it lives (Iriarte *et al*., 1990). A puma from the northern or the southern regions of their geographical population distribution is generally heavier than a puma from the central regions closer to the equator (Sunquist & Sunquist, 2002; Muphy & Macdonald, 2012). In Brazil, the body weight of pumas typically varies between 40 and 100 kg (NE, 2020). The body of a puma is long, skinny (Muphy & Macdonald, 2012) and covered by brown fur which is lighter in colour on their chest (Reis *et al.,* 2006). Bite marks located at the throat of the prey can be a sign of a puma attack, since pumas often kill through suffocation (Palmeira *et al.,* 2008). Usually, pumas start eating the prey from the ventral part (Pitman *et al.,* 2002). It is also common for pumas to cover the carcass of the prey with branches, foliage, soil or snow subsequent to a successful hunt (Shaw, 1989). This phenomenon is referred to as caching behaviour and is common among large, solitary felids (Schaller & Vasconselos, 1978; Sunquist, 1981). I have not found any study on caching behaviour among jaguars.

The wild prey base of pumas in Brazil consists of, among others, coati (*Nasua spp*.) (De Azevedo, 2008), deer (*Mazama spp*.) (Crawshaw & Quigley, 2002; De Azevedo, 2008), dasyprocta (*Dasyprocta spp*.) (De Azevedo, 2008), paca (*Cuniculus spp*.) (De Azevedo, 2008), capybara (*Hydrochoerus hydrochaeris)* (Engel, 2016) and armadillo (*Dasypus novemcinctus*) (Leite & Galvão, 2002). The method of killing preferred by the puma depends on the size of the prey (Branch, 1995): small prey are often killed with a bite in the neck while larger prey are typically killed through suffocation (Branch, 1995). The diet of pumas varies concurrently with geographical zone (Monroy-Vilchis *et al.,* 2009). Other factors affecting diet may include the availability and vulnerability of alternative types of prey (Sunquist & Sunquist, 1989, Malo *et al.,* 2004, Lozano *et al.,* 2006) as well as miscellaneous environmental factors. Pumas may hunt larger prey in habitats disrupted by human activity (Woodroffe, 2001), which can lead to increased predation on livestock in fragmented areas (Michalski *et al.,* 2006). In Brazil, pumas mainly hunt small to medium-sized prey (Engel, 2016).

Pumas need large habitats (Sweanor *et al.,* 2000). Their home ranges are between 32 and 1,030 km^2 in size (smaller for females) (Nowell & Jackson, 1996). When searching for food, pumas can move up to 9 km during the course of a single night (Beier, 1993). They live in several different types of habitats and occur both at sea level and at elevations of up to 5800 m (Sunquist & Sunquist, 2002). By contrast, they probably need specific kinds of environments in order to hunt effectively. The characteristic hunting technique employed by the puma is to stalk the intended prey animal (Sunquist & Sunquist, 2002). They can move quickly when covering short distance but do not engage in long-distance hunting (Sunquist & Sunquist, 2002). Therefore, as is the case with jaguars, pumas prefer habitats that provide concealment (Dickson & Beier, 2002; Foster *et al.,* 2010). During a study of puma attacks on deer undertaken in northwestern Utah and southern Idaho, the United States, 73% of deer were killed at forest edges, indicating that such scenes are suitable hunting environments for the puma (Laundré & Hernández, 2003). This type of environment probably gives the puma opportunities to observe the prey moving through the vegetation while the puma remains hidden (Laundré & Hernández, 2003). A study in California by Beier *et al.* (1995) found that pumas hunt by switching between moving and remaining stationary. That is to say, pumas wait at one place for a while and, if nothing happens, they move to wait at a new location (Beier *et al*., 1995). If no prey is taken, the pattern can be repeated for up to six times in the span of one night (Beier *et al*., 1995).

1.4 Predation on cattle in Pantanal, Brazil

Hunting jaguars or pumas is with a few exceptions prohibited by law in Brazil (Miotto *et al.,* 2011). Consequently, alternative methods for protecting livestock are required. In order to effectively formulate such strategies, knowledge concerning where predator attacks occur, and which groups of cattle that are primarily affected, is required.

Previous studies have shown that cattle in Pantanal stay close to water during the dry season, which provides jaguars with a concentrated source of prey to attack (Crawshaw & Quigley, 1991; Klar *et al.,* 2008). Similarly, during the wet season, cattle need dry areas during the night (Gese *et al.,* 2018) which will lead to more time being spent close to forests (Gese *et al.,* 2018). This may increase the risk for attacks, since jaguars and pumas prefer hunting close to dense cover (Dickson & Beier, 2002; Foster *et al*., 2010; Gese *et al*., 2018).

There are many studies suggesting that keeping cattle away from forest is a strategy which prevents attacks by jaguar and puma (Gese *et al*., 2018). For example, Quigley (1987) reported that all cattle killed in Pantanal during the study were located close to a forest. In a study by Palmeira *et al.* (2008) the mean distance between the kill sites and the nearest forest was reported as

1317 m. However, Gese *et al*. (2018) found attacks in many non-forest habitats and in addition considered keeping cattle away from forest an impractical proposition.

Moonlight can affect the behaviour of jaguars and pumas as well as that of cattle. In a study by Harmsen *et al*. (2011), it was found that jaguars and pumas have a similar circadian rhythm to that of their primarily consumed prey. The activity for amardillos and pacas was found to co-vary with moon illumination; being less active when the moon illumination was brighter. According to the same study, the activity of jaguar or pumas overall did not change with the moonlight. However, the activity of the jaguar during brighter moon illumination decreased in areas where there was much amardillos. It was suggested by the authors that jaguars hunted alternative prey due to the inactivity of amardillos during periods of brighter moon illumination. Cattle have been found to be more active at times of brighter moon illumination in a study by Sawalhah *et al*. (2016), whereas other studies have not found such a difference in activity (Dwyer, 1961; Wagnon, 1963).

1.5 Aims of the study

The purpose of the present study was to investigate the behaviour of jaguar (*Panthera onca*) and puma (*Puma concolor*) related to their hunting of cattle. The long-term goal of this study was to facilitate understanding and thereby help to reduce conflict between humans and wildlife in the area under consideration (Pantanal and Mato Grosso) and counteract the decline of jaguars in Brazil. Due to their status as near-threatened species that have disappeared completely from many habitats in Latin America, it is of particular interest to prevent further decrease in the number of wild jaguars and pumas. The specific objectives of the research presented in this thesis are:

I) to investigate which environmental factors (season, moon phase, vegetation) influence the likelihood of jaguars and pumas killing cattle
II) to investigate if the risk of cattle being killed by jaguars or pumas varies depending on certain characteristics (age, sex and breed) of the prey

2 Methods

2.1 The farms

The fieldwork for this study was performed at two farms: Sao Bento and Orvalho das Flores. Sao Bento (see figure 1) is located in Pantanal, the biggest wetland in the world (Alho *et al.,* 1988). Pantanal covers about 61700 km^2 in total (Brown *et al.,* 2012) and extends from western Brazil to parts of Bolivia and Paraguay (Quigley & Crashaw, 1992).

The period lasting from December to Mars is the largest rain season in Pantanal. From July to November Pantanal undergoes its dry season. During years with much rain, many areas can however remain flooded throughout entirety of the year. The average annual rainfall is 1200 mm (Quigley & Crashaw, 1992).

The periodic floods affect what kind of vegetation can exist in different subareas of Pantanal (Quigley & Crashaw, 1992); areas located at low altitudes have relatively open habitats consisting of grassland or cerrado whereas areas with higher altitudes consist of forest patches of different sizes.

Figure 1. Overview Sao Bento. (Photo: Google Earth)

Orvalho das Flores is located in Mato Grosso north of Barra do Garças south of the Amazon rain forest. In this area the climate is hot (semi-humid to humid) (Brown *et al.,* 2012). From May to October, Orvalho das Flores undergoes its dry season. The rainfall summed over the entirety of the year typically ranges from 1300 to 2300 mm.

In contrast to Sao Bento, the terrain around Orvalho das Flores does not consist of wetland, but quite open areas and sporadic forest patches (see figure 2).

Figure 2. Overview Orvalho das Flores. (Photo: Google Earth)

2.2 Data collection

Cattle data was obtained from the farms introduced in the previous section. At Sao Bento, studies similar to the current study had already been performed by former students at SLU (unpublished). Therefore, when finding a carcass, the ranchers had already noted the identity of the animal and the time when it was killed. From their databases information regarding breed, age and sex of the killed cattle were obtained. Similar studies had not been implemented on Orvalho das Flores prior to the current study, and the data presented in the following sections thus originates from a shorter period of time. For the same reason, information concerning the identity of the killed cattle was sometimes not available. Inference of predator species was made by the ranchers on the basis of whether the carcass was covered by foliage

(see example in figure 3), which indicates puma, or had any bite marks in the skull (see example in figure 4), which indicates jaguar. Foot prints were also a part of the decision.

Figure 3. Part of a skeleton covered with foliage, which indicates that the predator was a puma (Photo: Agnes Fridell).

Figure 4. Part of a skeleton with a bite mark, which indicates that the predator was a jaguar (Photo: Agnes Fridell).

At Sao Bento, cameras traps were set up at the locations of the carcasses following their discovery. This was not implemented at Orvalho das Flores. However, many of the cameras at Sao Bento were out of order during 2018. Cameras were thus used as an additional way to classify predator at Sao Bento only during 2017. The cameras used for the current study were Reconyx HC600 Hyperfire Motion-enabled cameras, which are motion sensitive and capture five pictures each time they detect a warm-blooded animal (see figure 5). During daytime, the cameras detected animals at an estimated distance of 24 m. During the night, the flash range of the cameras was limited to 18 m. The cameras were mounted on metal rods that were placed such that the cameras reached an average height of 80 cm measured from the ground. The main purpose of the cameras was to provide insight into which predator species and how many individuals were active in the surveyed area. The cameras also revealed if the area contains mothers and cubs or only solitary predators. Furthermore, the cameras continuously recorded time, moon phase and temperature. Data regarding moon phase was also obtained from the website www.timeanddate.com.

Figure 5. Jaguars documented while eating a carcass. Photo captured by a Reconyx HC600 Hyperfire Motion-enabled camera (Photo: São Bento).

All of the ranchers spoke Portuguese exclusively, so interpreters were used to be able to communicate effectively. The ranchers presented the spots where carcasses had been found, and GPS coordinates and vegetation type were subsequently registered. In order to acquire GPS coordinates, a mobile phone compass was used which provided coordinates in the WGS 84 reference system. The recorded type of vegetation was determined via subjective assessment based on visual inspection of (1) the spot, (2) photos and movies of the spot and (3) a satellite view of the spot via Google Earth. The distance between the carcass and the nearest forest edge was measured via Google Earth in retrospect. The data included in the study was collected during 2017 and 2018; some of it by other students prior to the start of this thesis project.

In order to analyse environment factors, the landscape around the location of predator attack was classified as belonging to one out of four mutually exclusive landscape categories: *forest*, *forest edge*, *partly open* or *open*. *Forest* landscape was defined as a location with dense tree or palm cover everywhere in a 15 m radius centered around the carcass. *Forest edge* was defined as a location where the carcass is within 15 m of an edge of a forest area (either inside or outside the area) which itself measures at least 10 m in radius. *Partly open* was defined as a location which is surrounded by an area, at least 7.5 m in radius, centered on carcass, consisting of bushes or smaller forest areas with diameters of less than 20 m. *Open area* was defined as a location with no bushes or trees within a 15 m radius from the carcass.

During 2018, one calf was attacked in a paddock and thus had no opportunity to escape. This calf was consequently excluded from the analysis of sex and age. However, it was included when the impact of spot, vegetation, season and predator species was examined.

ArcGIS was used to analyse and visualise results. Raster maps of the relevant areas were fetched from Google Earth and adapted to the reference system WGS 84 using geo-referencing in ArcGIS.

2.3 Statistics

The data were positively tested for normally distribution (Anderson-Darling test) and then analysed with either *t*-test or Anova GLM. All analysis were done in Minitab 18.

3 Results

A total of 53 attacks were recorded from 2017-01-01 to 2018-10-31. Out of these, 43 occurred at Sao Bento (see Figure 6) and 10 occurred at Orvalho das Flores (see Figure 7). 31 attacks were recorded in 2017 and 22 in 2018.

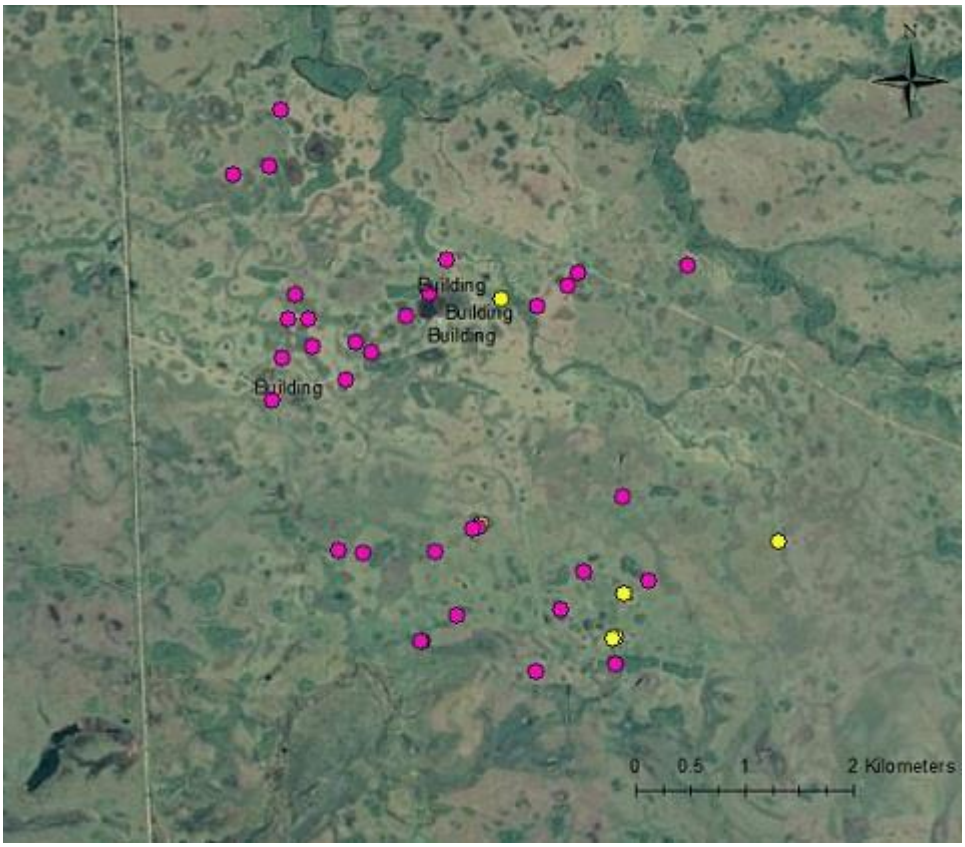

Figure 6. Attack positions around Sao Bento. Purple points are jaguar attacks and yellow points are puma attacks.

Figure 7. Attack positions around Orvalho das Flores. Only puma attacks.

3.1 Most affected groups of cattle by predator

Only data from Sao Bento were used since the age of calves at Orvalho das Flores was unknown except for two calves. The age in the sample of killed cattle was 169 ± 21 days (mean ± SE), range 2 – 391 days (see figure 8).

In this analysis, only data from Sao Bento is included since the data from Orvalho Das Flores in most cases did not included age or predator.

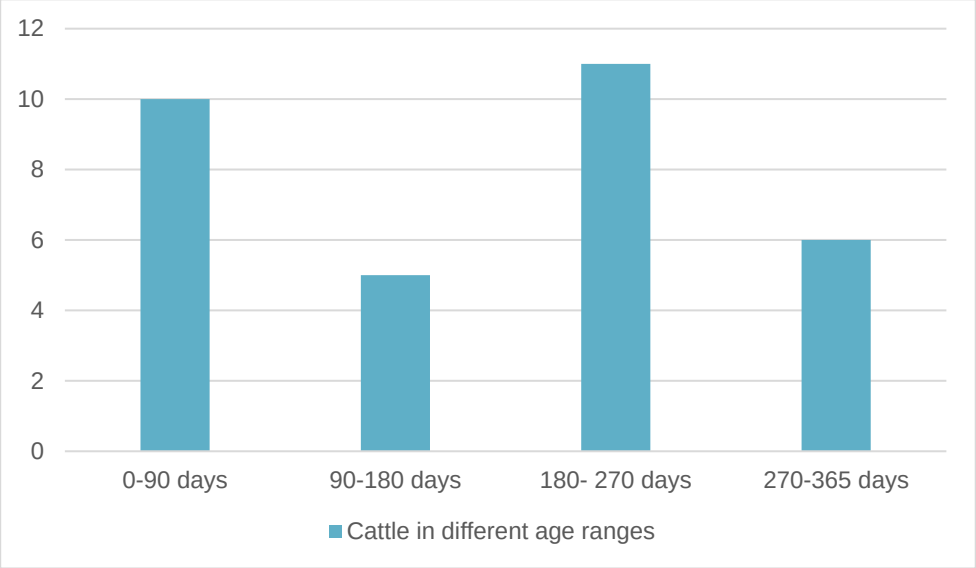

Figure 8. Numbers of cattle in different age ranges killed 2017-2018.

Out of all of the killed cattle, 48.08 % of animals were male, 40.38 % were female and 11.54 % were of unknown sex (see Figure 9). Since we did not know the proportion of male and female calves on the farm, no statistical analysis was done. However, most male calves were usually sold after weaning and most female calves kept.

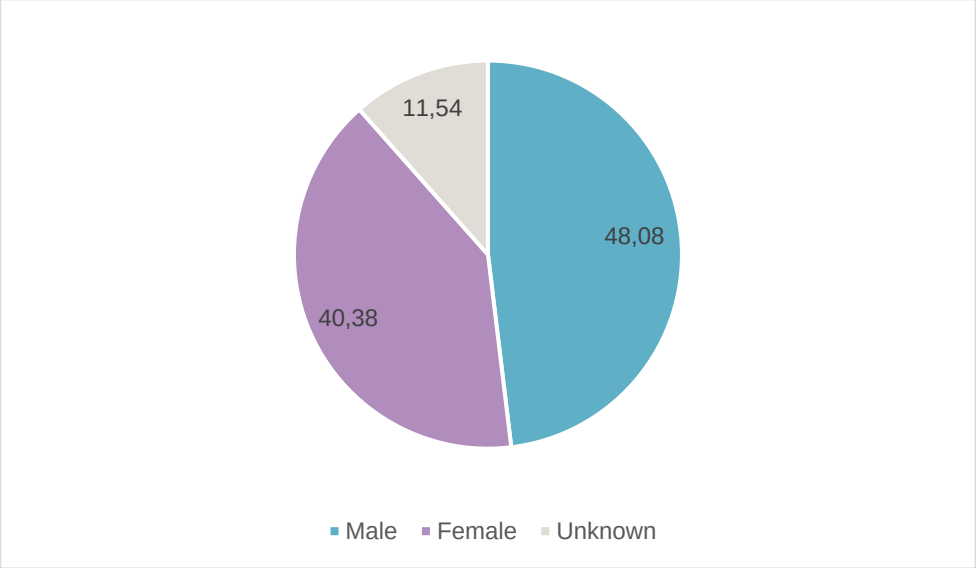

Figure 9. Proportion of sex of killed cattle 2017-2018. Since males were sold after weaning there was a higher proportion of females on the farms. Despite this, still more males were killed.

Breeds on the farms were mostly Nelore and Angus and some crossbreeds. No data about the proportion of different breeds on the farms were available to the current study. Because of this, it is difficult to determine whether some breeds were more vulnerable than others.

3.2 Vegetation types

Both farms had mostly open landscape with some forest patches, the latter especially at Sao Bento. The largest proportions of found carcases were registered in open and forest edge types of vegetation (see Table 1). Please notice that we recorded were the carcass was found, the attack might have happened somewhere else.

Table 1. *Numbers of attacks in different vegetation types at Orvalho das Flores (2018) and at Sao Bento (2017-2018). Carcasses were found most commonly in open areas and in forest edges.*

	Open	**Partly open**	**Forest edge**	**Forest**	**Paddock**
Sao Bento	25	2	12	3	1
Orvalho das Flores	2	1	4	3	0
Total	27	3	16	6	1

More attacks occurred at forest edges during 2018 compared to 2017 (see Table 2).

Table 2. *Numbers of attacks in different vegetation types in 2017 and 2018. More attacks occurred at forest edges during 2018 in comparison with 2017.*

	Open	**Partly open**	**Forest edge**	**Forest**	**Paddock**
2017	23	1	5	2	0
2018	4	2	11	4	1

The largest measured distance between a carcass and the closest vegetation area smaller than 20 m in diameter was 87.5 m. The largest measured distance from a carcass to a forest with a diameter of at least 20 m was 475 m.

Attacks sometimes occurred close to roads or houses. 16.98 % of attacks occurred within 100 m from a road and 7.55 % of attacks happened within 100 m from a house or stable. One attack occurred in a paddock.

3.3 Moon illumination

Data regarding moon illumination was collected for attacks reported at Sao Bento, but not Orvalho das Flores. A larger proportion of the attacks occurred at less bright moon illuminations than at brighter moon illuminations (see Figure 10).

The 669 days of the study were grouped split up into three group with n = 223 days each according to the light intensity the moon, see table 3.

Table 3. *Days of the study distributed in groups with different moon phases and 223 days in each group.*

Moon phase	N (days)	Mean light (%)	Minimum	Maximum
New Moon	223	10.408	0.0	28.8
Half Moon	223	54.775	28.8	78.8
Full Moon	223	93.412	79.1	100.0

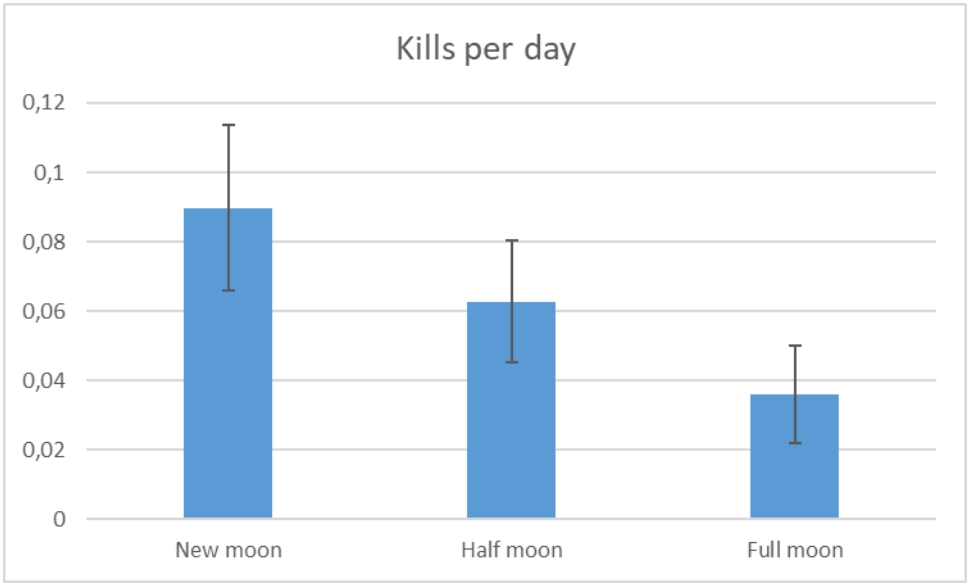

Figure 10. Mean number of kills per day ± SE according to moon phase.

The mean moon illuminance on days when calves were killed was 41.8 ± 5.1 %, compared with 53.3 ± 1.4 % with no killings (P= 0.03, DF 1, T-value 2.19, *t*-test) (see figure 11).

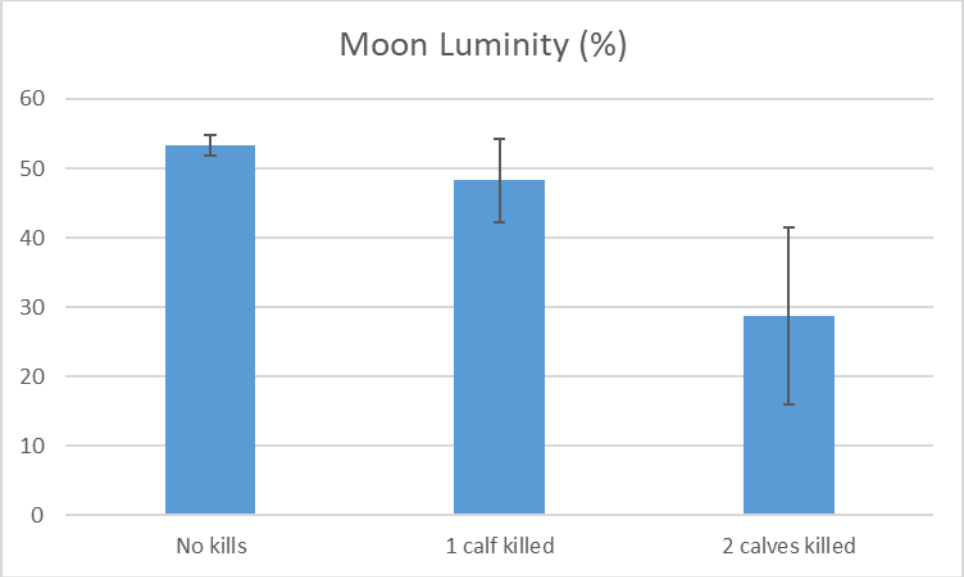

Figure 11: Moon illumination on days with 0, 1 and 2 kills, respectively.

3.4 Season

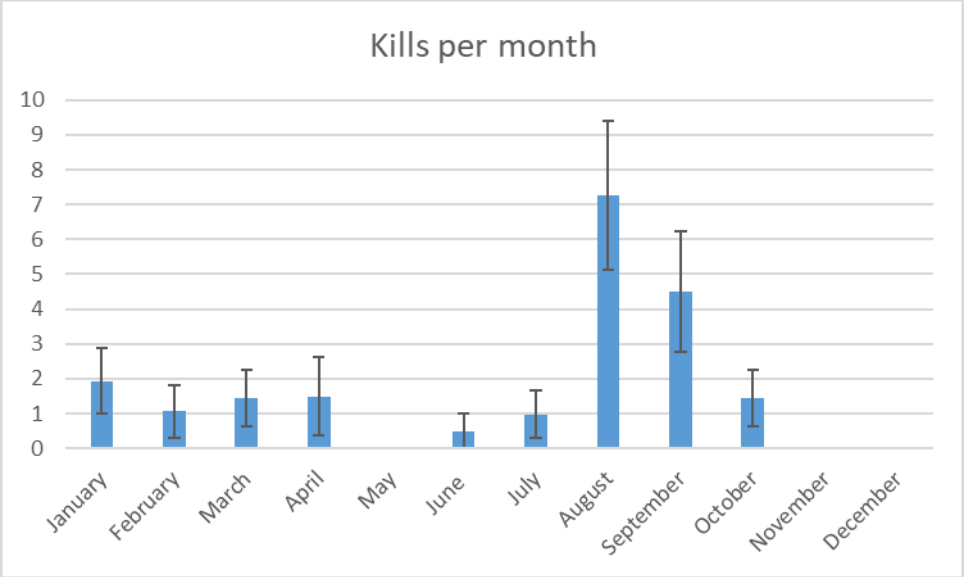

Figure 12; *Number of attacks distributed at different months at Sao Bento in 2017. Most of the attacks occurred during August and September (the data is adjusted for 30 days per month).*

In 2018, fewer attacks occurred at Sao Bento in total. Attacks were at that time most common in forest edges (see Table 4).

Table 4. *Numbers of attacks distributed at different months at Sao Bento in 2018. Most of the attacks occurred in forest edges during July to September.*

	Jan	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**
Open vege-tation	0	0	0	0	0	0	0	1	0	1
Partly open vege-tation	0	0	0	0	0	0	0	0	1	0
Forest edge	0	0	0	0	0	0	2	2	2	1
Forest	0	0	0	0	0	0	0	1	0	0
Pad-dock	0	0	0	0	0	0	0	0	1	0

Since only two of the attacks recorded at Orvalho das Flores had their date documented, no seasonal analysis was made with the data collected from that location.

3.5 Predator

In this analysis, only data from Sao Bento is included since the data from Orvalho Das Flores in most cases did not included age or predator.

The mean age of cattle killed by jaguar was 199 ± 19,5 days (mean ± SE) with a range 2 – 291 days. The mean age of cattle killed by puma was 4.8 ± 1.2., range 2 - 8 days. Hence, the calves killed by puma were by far younger than the one killed by jaguar (P<0.001, *t*-test). Figure 13 shows the age of prey killed by jaguar in comparison with prey of puma.

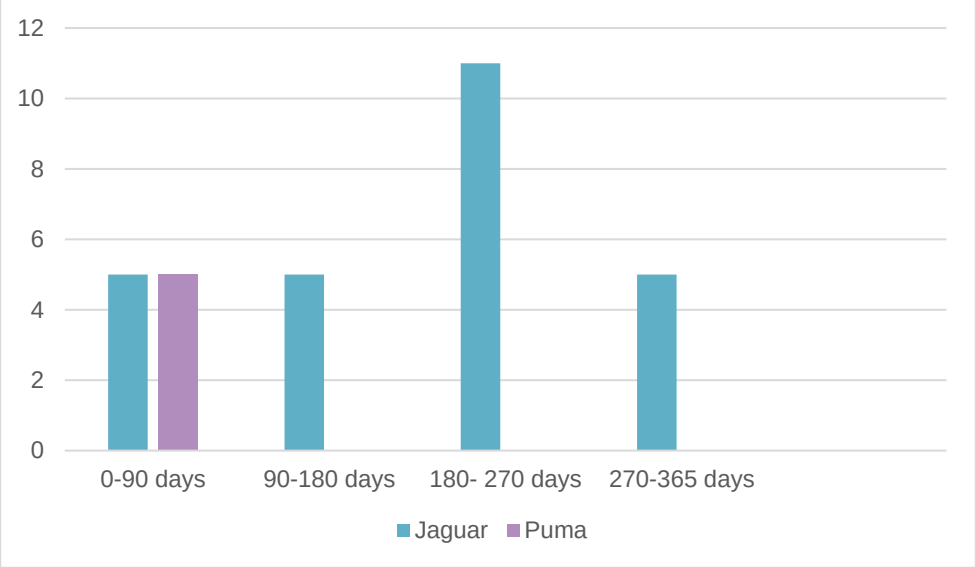

Figure 13. Numbers of cattle in different age ranges killed by jaguar and puma 2017-2018. Pumas only killed cattle 0- 90 days old while jaguars most commonly killed cattle 180- 270 days old.

For jaguars, no difference in frequency could be detected between the sexes of killed animals. For pumas, no tendencies regarding prey sex preference could be determined since sex information was missing in nearly a third of recorded cases.

4 Discussion

4.1 Discussion of the results

4.1.1 Environment factors affecting jaguar and puma killings

4.1.1.1 Season

In the present study was a clear difference in the preferred killing frequencies between months. According to the data collected during 2017, most attacks in the open area took place in August (during the dry season) and most attacks on forest edges occurred in January (during the rainy season). This is confirmed by previous studies such as Gese *et al.* (2018) who found that cattle spend more time in forests during the rain seasons. Previous studies have also found that cattle spent more time closer to water during the dry seasons (Crawshaw & Quigley, 1991; Klar *et al*., 2008).

Aggregated over the entirety of the dataset, most attacks occurred in August and September. In contrast to previous studies, this indicates that jaguars and pumas preferred to hunt cattle during the dry season. Alternatively, the result could be a result of how the cattle density differed between months or be related to calving season or abundance of wildlife, which cannot be confirmed nor refused by the available data of the present study. Based on previous studies, the expectation was that most attacks would occur during the rainy season, when cattle are expected to spend more time in forest environment (Gese *et al*., 2018) and thus be more vulnerable to predators who tend to hunt at forest edges (Dickson & Beier, 2002; Foster *et al.,* 2010; Gese *et al.,* 2018).

Some reasons for more attacks occurring during the dry season are related to routines employed at the farms, such as birth giving and weaning. It is also possible that jaguars and pumas are in need of more prey during the dry season. There is, however, no obvious reason to expect this, as both

jaguars and pumas can have cubs throughout the year (Brown, 2006). However, the loss of calves in the present study was probably due to few individual predators. Since we do only partly know when they had offspring, this factor could not be investigated.

Another potential explanation might be variations in access to natural prey. Older (and thus larger) calves appear to have been killed more often during the dry season according to the current study. This could indicate that fewer large natural preys are available during the dry season. According to Novack *et al*. (2005) it is more energy-efficient to take larger rather than smaller preys, and as a result predators could be motivated to hunt comparatively large cattle instead of smaller, naturally occurring prey. However, the amount of available mammal biomass varies with season in Pantanal, with highest abundance during dry season (Alho, 2008). Larger natural prey that are consumed in the area are deer (*Mazama sp.*) and capybara (*Hydrochoerus hydrochaeris)*, both by jaguar (Engel, 2016) and by puma (Crawshaw & Quigley, 2002; de Azevedo, 2008; Engel, 2016). The size of capybara groups is larger in the dry season than in the rain season (Alho, 2008). As such, the hypothesis that jaguars and pumas kill more cattle in dry seasons due to a deficiency of natural prey thus seems unlikely to hold true.

If the population size of cattle varies seasonally due to, for example, variation in the rate of births and weaning/selling takes place during dry season, it could potentially explain the seasonal variance of killed cattle. Yet, since the risk still seems to be greater during the rainy season, cattle are expected to spend more time in forest environment according to Gese *et al*. (2018), a change in time for breeding is not recommended. A preferable approach is to develop strategies for protection of calves during hazardous periods.

4.1.1.2 Vegetation types

Based on previous studies (Quigley, 1987; Palmeira *et al.,* 2008; Gese *et al*., 2018), most of the carcasses were expected to be found at forest edges. In contrast, about double as many carcasses in the current study were found in open or half-open terrain, compared to forest or forest edges. It can, however, be argued that many attacks occurred close to forest in a relation to forest availability, as both farms consist of mostly open vegetation. This means that forest and forest edges counted for more attacks than open areas, in relation to the habitat sizes. Therefore, it seems plausible that the predators use forests for the purpose of stalking cattle or at least for hiding the carcass. Another explanation is that forests might be used by predators to cover the carcass of their prey in order to return later.

As discussed in previous sections, season conditions could be a potential reason to why attacks occur in forest or open vegetation (Crawshaw & Quigley, 1991; Klar *et al*., 2008; Gese *et al*., 2018). The grass height could be of crucial importance, since high grass differs throughout the year and

could hence have affected attacks in open vegetation. However, there is no collected data about the grass height with which to test this hypothesis. Another explanation could be differences in the grazing systems employed by the farms, about which there are no information.

Attacks on Sao Bento happened close to roads and houses relatively often, and in one case even in a paddock. It can thus be suggested that jaguars and pumas in the studied areas were not afraid of people, or alternatively, that they have difficulties finding enough natural prey in their respective areas. If true, this prospect could result in increased human- wildlife conflict, since it is a higher risk that the predator is observed.

4.1.1.3 Moon illumination

According to the collected data, moon illumination affected when cattle were killed. Jaguars killed the most cattle when moon illumination was less than 25%. Most of the attacks occurred when moon illumination was lower than during nights without attacks.

In 2014, Prugh and Golden conducted a meta-analysis on how nocturnal mammal are affected by moon phases. They tested the hypothesis that prey species that rely on vision are more active during full moon while predators reliant on vision are less active during full moon. In that study, lions were found to be less active during periods with brighter moon illumination. However, a study by Cozzi *et al.* (2012) found that the activity of lions did not differ significantly between different moon phases. Rockhill *et al*. (2013) showed that bobcats were more active during brighter moon illumination. It can therefore be assumed that the effect of moon phases on predator behaviour differs depending on prey and competing predators.

A study by Harmsen *et al*. (2011) found that jaguars and pumas are generally not affected by moon illumination, but that jaguars change their circadian rhythm in areas in which armadillos are their main prey. Importantly, armadillos are less active during bright moon illumination. A possible explanation for this might be that armadillos adapt their circadian rhythm as a survival strategy, since their predators see better in brighter moon illumination. If cattle are the main prey of jaguars in Pantanal, such results indicates that cattle would be less active during bright moon illumination. However, confounding the issue further, higher intensities of moon light have been associated with more activity among cattle in a study by Sawalhah *et al*. (2016), while other studies have found no differences in activity between different moon phases (Wagnon, 1963).

In a study by Huck *et al.* (2017), deer were found to be more active during periods with a full moon. As a result, jaguars may hunt them instead of cattle during periods with bright moon illumination. It is also possible that jaguars have changed their circadian rhythm in order to hunt a main prey that is less

active in full moon, like armadillo. This line of reasoning would indicate that cattle are not the main prey of jaguars in the area. Another possibility is that cattle have such bad night vision when compared to jaguars and pumas that they are much easier to attack in low moon illumination. In that case, a full moon would benefit cattle more than it would jaguars and pumas.

The differences in the tendencies of jaguars and pumas to hunt in full moon or not could be an effect of them historically hunting different species naturally (De Azevedo, 2008; Engel, 2016), which could have led to the development of distinct strategies. Hypothetically, such behavioural divergence could be a result of benefits provided by avoiding conflicts with each other.

Since cattle seem to be slightly more active in brighter moon illumination (Sawalhah *et al*., 2016) it can be conjectured that they feel relatively safe in full moon, or that they can forage easier. Incidentally, it makes intuitive sense that jaguars and puma would be able to see relatively good in dark. With this in mind, it is realistic that predators would mainly kill cattle in less bright moon illumination. It could be of interest to further study the impact of illumination on predation. Rockhill *et al*. (2013) have suggested that including moon phases in a modelling and examining of the population dynamics of prey would be useful.

4.1.2 Affected groups of cattle

4.1.2.1 Age

Our results showed that mainly younger animals were affected by predation. There were, however, attacks on animals over 1 year old, but at a lower frequency. More cattle between 180- 270 days old were affected than was expected *a priori* because many of the calves older than six months were sold already and hence less of them present at the farm. Yet, many older calves were killed, maybe as a result of weaning (Peña- Mondragón *et al*., 2016). The average age of cattle killed by jaguar was 6.6 months in the current study, which is consistent with a previous study by Palmeira *et al*. (2008) where the average age was 3-9 months. In that study, the average age of the prey killed by a puma was 3 months, which is higher than that observed in this study where puma-killed calves were about one week old. However, the age was in the current study only registered for eight of the puma attacks, which makes the results highly uncertain. With a larger sample, the average age might have been higher.

According to Palmeira *et al*. (2008), a possible partial solution to the problem of predation on cattle is to use concentrated breeding of calves in order to protect them during the early stages of life. However, Michalski *et al*. (2006) noted that protection of calves has to last for at least three months following birth in order to be effective. Palmeira *et al*. (2008) found that calves younger

than nine months constitute the group most often subject to predation with fatal outcome. According to the same study, the average weight of calves at the time of death was 74 kg in cases involving pumas and 144 kg in cases involving jaguars (Palmeira *et al*., 2008). The typical age of calves was up to six months old when killed by pumas and 3- 9 months when killed by jaguars (Palmeira *et al*., 2008). Additionally, males were more often killed than females (Palmeira *et al*., 2008). Several other studies have shown that calves are the group of cattle most affected by predation (Schaller, 1983; Hoogesteijn *et al*., 1993; Polisar *et al*., 2003; Michalski *et al*., 2006). According to Peña-Mondragón *et al*. (2016) there is a risk of increased predation if the calves are weaned at a young age. All in all, weaning is ranked as a low risk factor in relation to factors such as proximity to forest and not monitoring the calves.

It is estimated that the size of calves that were killed differs greatly between areas, depending on how much natural prey are present in the zone. The age of the killed cattle can also be affected by whether the cattle farmers are monitoring the calves during the early periods of life and, if so, for how long. According to Michalski *et al.* (2006), a protection scheme would have to last for at least three months following birth in order to be effective. In the current study, 63% of the killed calves were older than three months, so even a three-month long shelter time would probably not have been enough. Protection of young calves can potentially be practical in places where pumas are the main threat. In areas with many jaguars, weaned calves may have a higher risk to be killed.

4.1.2.2 Breed

It is difficult to determine if Nelore or Angus were more vulnerable to different degrees, since information concerning the proportion of breeds at the farms was not included in the current study.

According to some of the consulted farmers, Nelore are more aggressive than Angus. Nelore origins from Asia where there are big cats like leopard, whereas Angus is a breed original from Scotland. It is possible that differing mother instincts between the breeds make their respective calves dissimilarly vulnerable. It is also possible that the two breeds have developed different strategies in order to avoid predators or to defend themselves against them. Also Nelore being more aggressive than Angus could explain why on aggregate Nelore were killed when they were younger than Angus.

According a study by Hoogesteijn and Hoogesteijn (2008) neither Nelore nor Angus showed defensive behaviour against predators. Linnell *et al*. (1999) argue that domestic cattle have lost nearly all of their former anti- predator behaviours. Flörcke and Grandin (2013) also considered domestic cattle to have remarkably low levels of anti- predator behaviours. To their knowledge, their study was the first to show a connection between predation and cattle

temperament. They used hair whorl pattern on the cattle's forehead to measure temperament. Cows without facial hair whorl pattern had higher calf losses due to predation. They also noted that calves without facial hair whorl pattern were less afraid for unknown objects and/or persons. From this weight of evidence it seems plausible to conclude that temperament can affect the risk for death by predation. If such is the case, it would be interesting to study whether Nelore and Angus have mutually different anti- predator behaviours. Apart from the aforementioned method utilizing hair whorl pattern, temperament can be assessed in other ways; for example via flight speed, serum cortisol measurement and mobile confinement (Aldrighi *et al*., 2019). It should therefore be possible to use already established methods to examine temperament in Angus and Nelore.

4.1.2.3 Sex

Overall, no difference in how often the different sexes were affected was detected by the current study. The fact that slightly more males were killed was unexpected, since many of the bull calves are usually sold once weaned. Therefore, the number of female calves on the farm is expected to exceed the number of males. Males were overall taken at younger ages than females.

Previous studies by Palmeira *et al*. (2008) and Soto-Shoender and Giuliano (2011) found that male calves have a higher risk to be killed by predators than females. According to Palmeira *et al*. (2008) this could be an effect of male calves moving farther from the mother cow than females of the same age. A study in Israel by Yom-Tov *et al*. (1995) found that male calves were more frequently killed by golden jackal (*Canis aureus*) than females. This is thought to be a consequence of male calves being heavier. It would certainly be interesting to study if female calves in fact tend to stay closer to the mother cow in comparison to male calves. Such a study could be made with GPS collars on calves and cows. Furthermore, the hypothesis by Yom-Tov *et al*. (1995) regarding differences in weight could similarly be examined easily. I also contemplated if males and females have different activity patterns during the night. Even this effect would be possible to capture with GPS- collars.

4.1.3 Prevention strategies

The results acquired by the current study indicates that calves younger than 3 months was well as calves 6-9 months of age are risk groups. The increased risk when calves were 6-9 months old could be explained by the fact that they are recently weaned and therefore extra vulnerable (Peña-Mondragón *et al*., 2016). Due to this fact, it is important to protect calves more after weaning.

Keeping livestock away from forests is a strategy that has often been proposed in previous studies (Quigley, 1987; Gese *et al*., 2018). However, it has many potentially negative side effects. For example, biodiversity decreases if the forest parts are devastated. The welfare of cattle could also be negatively affected, as the forest offers dry areas to rest at during the rainy season and protection from the sun. Besides, Geese *et al*. (2018) points out that attacks still take place in varying habitats. This is confirmed by the current study, where attacks were observed also in open areas. Regardless, it is presumably a good idea to let more forest parties be grazed by older cattle while moving cattle at increased risk of being attacked (calves and the recently weaned) to more open pastures.

Since wild cat density is high in Pantanal (Zimmermann *et al*., 2005; Marchini & Macdonald, 2012), one possibility is to breed calves at a different location in Brazil and keep older cattle in Pantanal. Farms would thus need to specialize to a greater extent. The disadvantage of this approach is that it would result in a greater need for transport, which is a stress factor for cattle, causes costs and entails a risk of spreading infection between farms (Swanson & Morrow-Tesch, 2001).

Vulnerable population calf groups could also be manually guarded. However, it is a difficult task indeed to monitor livestock in a large area. Conversely, decreasing the size of the grazing area would adversely affect the growth of the calves. Guarding is also labor-intensive, and is probably most effective during the nights, which means uncomfortable working hours. Such a strategy could also increase the human predator conflict, as the risk of livestock farmers encountering pumas and jaguars would increase. As a result, the risk for poaching increases, which would threaten the conservation work for jaguars and pumas.

Hoogesteijn and Hoogesteijn (2008) suggested that water buffalo might be used to guard cattle against jaguars and pumas. Buffalo show defensive behaviours against predator more than cattle do, and predation on buffalo by jaguar and puma is lower than on cattle (Hoogesteijn & Hoogesteijn, 2008). In Venezuela, where the study was conducted, there is however low demand for buffalo meat. Also, the authors argue that there is a risk of buffalos returning to their feral condition if kept as livestock. Water buffalos can even have a negative impact on the environment through mechanisms such as over- grazing and trampling if not appropriately managed (Hoogesteijn, 2001).

Fences are used against predators in for example Australia in order to keep wild dogs away (Bommel & Johnson, 2014), or in Sweden against wolves (Karlsson & Sjöström, 2011). However, fencing against jaguar and puma is a more difficult task, if not impossible. It would probably be difficult to build an effective fence against jaguars and pumas, as they are both proficient climbers and jumpers. A fence constructed for this purpose would therefore have to be high and all the trees in the vicinity would have to be cut down.

This would affect the biodiversity negatively and the fence would likewise prevent other, harmless animals from moving through the area. In addition, construction of fences would probably be expensive and laborious.

Cattle seem to be at higher risk for predation immediately following weaning. If they are instead killed when at a higher age, it is more economically motivated to prevent attacks since the farmers have already invested in them during breeding. Still, the methods have to be efficient enough in order to motivate the cost.

4.2 Discussion of methods

4.2.1 Possible sources of errors

As this is a rather small dataset containing 53 killed cattle subject to limited analysis, there is a need for further research on the questions posed here. It had of course been good to involve more farms and more years but this had been too demanding for a master study.

How the vegetation was classified is a factor that could affect results substantially. An assessment was made in which a forest of at least 20 m in diameter was classified as a larger forest and that a 15 m radius from the carcass was a suitable distance to use. With this selection made, a large part of the data was then classified as open landscape. Also, pumas can pull a prey 200 m (Laundré & Hernández, 2003) which means that the location where the carcass is found is not necessarily the place where it was killed. Of course, with another classification, the results could have been different. But since we have clear definitions of vegetation zones, our results can still be compared with other studies.

Data collection was done partly by several people, which means that the subjective elements of data collection may differ. However, since we had clear definitions when collecting data we think that this did not cause any problems. Also, the same senior researchers were involved and in both years on the farms, although with different students.

4.2.2 Improvement of the method

The data collection procedure could be improved upon in a multitude of ways. Firstly, data about cattle which were not killed should be collect in order to enable statistical analysis and comparisons with base rates. If we had the exaxt composition of the cattle herds, like age, sex, breed etc., we

could have compared the traits of killed cattle with the traits of the entire herd. Knowledge of the Portuguese language could also have facilitated the work undertaken, as I would then have been able to communicate directly with the ranchers. However, the study was conducted together with English-speaking Brazilian colleagues and we do not think that communication problems led to any errors.

The person making the decision regarding what kind of predator killed the cattle was in this study different for the different farms. To increase data quality, it is important to make sure that a knowledgeable person always makes the assessment of the found carcass in an as objective manner as possible. We addressed this by removing all carcasses from the data set when it was not possible to gain in a reliable way. As the predator responsible for the killing often returns to the carcass later to eat (Sunquist & Sunquist, 1989), another way to make a more reliable classification of the predator is to set up motion-sensitive cameras at the location of the carcass. The proposition that the depicted predator is the same as that which generated the carcass is not entirely certain, but this method is here conjectured to facilitate a more reliable assessment than visual inspection of the scene after the fact. Such cameras were set up on Sao Bento, but as they had not been maintained at the onset of this study they could not be used during 2018. At Orvalho das Flores, they were not used at all but will be after my time there.

The acquired data could be made better if missing cattle are found and investigated sooner after their disappearance. Therefore, it is important that those who work at the farm are involved and understand the aims of the study and document the attacks. It might be advantageously to encourage those who work at the farm to record GPS coordinates themselves when a carcass is discovered, as this can be done easily with a regular mobile phone. They could also film the site so that the vegetation can be analysed as it was at the time of the attack. The overall efficiency of work could be increased if the farmers were to document more, as it would reduce the risk of having to return to the site at a later time.

It is advantageous that the study was conducted over the course of two years. Since the data is collected from different times of the year it is easier to make seasonal analyses. Still, more data from Orvalho das Flores would have given a more generalizable representation of the hunting preferences of pumas, since so few puma attacks were recorded at Sao Bento. This was the first study at Orvalho das Flores, and it could be of interest to conduct additional studies over different seasons. However, predator attacks have according to the farmers always been a bigger problem at Sao Bento than at Orvalho. During further studies the methods can develop together with the ranchers, which could lead to the data collection getting better. It would of course also be better to involve more farms.

4.2.3 Possible ethical and societal consequences

The purpose of the study was to give the farmers in Pantanal knowledge of the jaguar´s hunting behaviour that they can use to protect their livestock. The goal is that it can be achieved without hunting as many jaguars. Hopefully, the conflict between human and wildlife can be reduced and a better co-existence achieved.

Neither the cattle or the wild cats was directly affected by the study since it was made as an observation study. No changes were made in their environment.

4.3 Further studies

To further the goals of the current study, data regarding cattle that are not killed should be collected and used for a statistical analysis. Also, it could be interesting to collect more data from a variety of seasons. Perhaps different actions against predators are more or less effective depending on the season? Differences in predation frequency depending on the season could provide valuable insight into important determinants of jaguar and puma hunting techniques, and perhaps also reveal something about in which situations they have difficulties to hunt their natural preys.

It could also be interesting to study whether weaned calves are a risk group. If such was the case, it would be interesting to study differences in effect between prevention strategies such as keeping them in group with older cows, keeping them away from forests or guarding them.

Since males seem to be more affected by predation than females, specifically testing some of the hypotheses purporting to explain why it differs could be of interest. For example, it could be studied whether males tend to stray farther from the cow than females.

Not much previous work seems to have been undertaken with the goal of differentiating behaviour against predators between Nelore and Angus. This would probably been an interesting area for further research. Since methods for assessing temperament in cattle are already available at the time of writing, it would probably be possible to conduct such research using already verified methods.

I have only found one study on how jaguar and puma activity change in relation to moon phase. I found a few studies on cattle activity dependent on moon phase, but no study on whether cattle predation frequency varies by moon illumination. This too could be interesting to study.

5 Conclusions

The aims for this study were to investigate how environmental factors and certain characteristics of the cattle influence the likelihood of jaguars and pumas killing cattle. Conclusions that can be drawn are that hunting of cattle occurs in different environments with varying degrees of vegetation. In relation to the prevalence of forests, many attacks still took place near forests. Attacks sometimes occurred within 100 m of a house or stall. Overall, most of the attacks occurred when moon illumination was at less than 25%. Most of the attacks occurred in August and September, which is during the dry season. Seasonal variations seem to be an effect of farm routines rather than an environment effect.

The available data also showed that attacks can occur on cattle of varying ages of up to over 1 year. Most killed calves were less than 90 days old or between 180- 270 days old. Pumas took younger animals than jaguars in aggregate. Nelore were most affected by attacks when they were 180-270 days old while Angus were more often taken when they were 270-360 days old. Males seems to be at higher risk for being killed than females.

Since there are several disadvantages with most of the protective strategies, my conclusion is that the best strategy currently available is to implement seasonal breeding, where births and weaning coincide with the dry season which seems to be a safer period according to the literature search. If possible, it would probably be advantageously to keep calves away from forest areas until they are over 1 year old and are at lower risk of being attacked. Lastly, it is important to promote habitats for jaguars and pumas around Brazil to prevent individual animals from being tempted to take cattle by way of having good access to wild prey.

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