Activity patterns, diurnal and nocturnal behaviour of the marsh deer (*Blastocerus dichotomus*) in the Jataí Ecological Station, Brazil

Aktivitetsmönster och dygnsrytm hos sumphjort (Blastocerus dichotomus) i Jataí Ecological Station, Brasilien

Lina Lehndal

Sveriges Lantbruksuniversitet
Institutionen för husdjurens miljö och hälsa
Avdelningen för etologi och djurskydd

Skara 2008

Studentarbete 211

Swedish University of Agricultural Sciences
Department of Animal Environment and Health
Section of Ethology and Animal Welfare

Student report 211

ISSN 1652-280X

Activity patterns, diurnal and nocturnal behaviour of the marsh deer (*Blastocerus dichotomus*) in the Jataí Ecological Station, Brazil

Aktivitetsmönster och dygnsrytm hos sumphjort (Blastocerus dichotomus) i Jataí Ecological Station, Brasilien

Lina Lehndal

Examensarbete, 30 poäng
Naturvetarprogrammet inriktning biologi, Uppsala Universitet

Handledare: Jens Jung, SLU, Box 234, 532 23 Skara

Content

Abstract

The marsh deer (*Blastocerus dichotomus*) is the largest cervid in South America. It is morphologically adapted to the marshes and floodplains that constitute its habitat. The global distribution of the marsh deer has been reduced with 65 % in the last four decades, due to habitat destruction and fragmentation, caused by agriculture, cattle grazing and the construction of large hydroelectric dams. It is now threatened with extinction in Brazil. In 1998, five marsh deer were reintroduced in the Jataí Ecological Station, São Paulo State, Brazil, and the population had in 2006 increased to about 20 animals. In this study, we tagged three female marsh deer from the Jataí population with GPS-collars, and from two of them we successfully received data. The marsh deer's activity was recorded in intervals of 5 to 10 minutes, 24 hours a day and for several months, which has never been done before in this species. Activity was measured in two ways; as neck movements and as distance moved in between two recorded time intervals. My results showed that the marsh deer were primarily nocturnal, but with some diurnal activity, especially in the afternoon, whilst activity at dusk and dawn was low. The deer seemed to have moved more in January-February than in November-December, whereas the amount of neck movements did not change over time. No difference between areas used at day and night was detected for the focal animals. The reason for the marsh deer's activity pattern is suggested to be partly due to predator pressure, but the main explanation seems to be environmental conditions, notably temperature. To draw reliable conclusions on the activity patterns of the Jataí-population throughout all seasons, further studies with larger sample sizes and a study period over at least one year would be needed.

Sammanfattning

Sumphjorten är Sydamerikas största hjort. Dess habitat utgörs av träsk och flodbäddar vilket den har anpassats till morfologiskt. Sumphjortens globala distribution har reducerats med 65 % under de senaste fyra decennierna, på grund av habitatförstörelse och -fragmentering, som orsakats av jordbruk, bete av boskap och stora dammbyggen. Sumphjorten är nu utrotningshotad i Brasilien. År 1998 återintroducerades fem hjortar i Jataí Ecological Station i delstaten São Paolo, Brasilien och år 2006 hade populationen ökat till cirka 20 individer. I denna studie märktes tre vajor från Jataí-populationen med GPS-halsband, och från två av dessa genomfördes en lyckad datainsamling. Sumphjortarnas aktivitet registrerades med tidsintervall av 5 – 10 minuter, dygnet runt under flera månaders tid, något som aldrig tidigare gjorts för denna art. Aktiviteten mättes på två sätt, både som antal nackrörelser och antal meter som hjorten förflyttat sig mellan två mätintervall. Resultaten visade att sumphjorten framförallt var nattaktiv men med viss aktivitet under dagen, främst under eftermiddagen, medan aktiviteten var låg vid skymning och gryning. Hjorten förflyttade sig mer i januari-februari än i november-december, medan antalet nackrörelser inte förändrades beroende på månad. Jag fann ingen skillnad mellan vilka områden som användes på dagen och på natten av de studerade djuren. Sumphjortens aktivitetsmönster kan delvis förklaras med predatortrycket, men den främsta orsaken verkar vara miljöförhållanden, framförallt det varma klimatet. För att kunna dra några säkra slutsatser om Jataí-populationens aktivitetsmönster över olika säsonger behövs ytterligare studier med större provstorlek och en studieperiod på minst ett år.

Introduction

Activity patterns in animals

Most animals divide their time into two fundamentally different behavioural states: activity and rest. All species have their unique way to allocate their time and energy budgets in order to maximize fitness. There are many factors that affect activity patterns of animals. Some examples of factors that can play important roles for the activity patterns are cycles of light or darkness, phases of the moon, biological cycles, temperature cycles, regular feeding bouts, and predation risk (Kamler *et al.* 2007).

Some species benefit from being active during the day, others at night, and others again have more or less even activity over a 24-hour period. There are also variations within species, depending on environmental conditions, which can vary a lot during a 24-hour period. Temperature and humidity change, so do light and darkness. Nocturnal species are active during darkness; diurnal species are active during broad daylight while crepuscular species primarily are active at dawn and dusk. Some species with short activity cycles are active both at day and night (Halle & Stenseth 2000).

Ungulates are, with a few exceptions, normally active during both day and night. The periods of activity are interspersed with resting phases spread throughout the 24 hours (Leuthold 1977). When I use the terms diurnal (most active at daytime), nocturnal (most active at night) or crepuscular (most active at dusk and dawn) in this text, I refer to the time of a 24-hour period when the animal exhibits the highest amount of activity. This does not imply that it is completely passive or asleep for long periods at other times of the 24 hours, only that the mean activity is lower.

The difference in climate in different seasons also affects the behaviour. In tropical areas the rainy and the dry seasons may generate different activity patterns. Seasonal changes in activity patterns among ungulates are governed mainly by the availability and quality of food and/or water. In the dry season, food is not only less abundant but also has a lower quality (Leuthold 1977). In the rainy season, when plants are fresh and young, they contain less fibre but more energy and protein and are therefore more easily digested. Hence, the seasonal changes can affect the length of ruminating bouts and their distribution throughout the day (Leuthold 1977).

In temperate areas, animals tend to rest more in the winter. In ruminants, this is due to lower food quality which requires longer digestion time, thus more rest. This has been shown for Roe deer (*Capreolus capreolus*) and moose (*Alces alces*) in Scandinavia (Cederlund 1989), and for red deer in Europe (Kamler *et al.* 2007).

The costs and benefits of resting or being active at a certain hour vary a lot between species. For a predator, the activity pattern of the prey play the most important role, but other factors such as competition due to coexistence with other species matter also. For prey on the other hand, being active at the time of day when the predation risk is lowest is generally the most beneficial (Halle & Stenseth 2000).

In herbivores, food availability does not change during the course of the day, thus activity patterns are rather governed by environmental conditions, predator pressure and digestive abilities such as metabolic rate (Halle & Stenseth 2000). Digestive abilities are especially important in ruminants, whose digestion system requires regular periods of rest to function properly. The length of the resting periods is highly dependant on body mass in ruminants, where small animals generally require more rest than large ones (duToit & Yetman 2005).

To my knowledge, there are no reliable previous records of the diurnal behaviour or activity patterns of the marsh deer. Pinder & Grosse (1991) states vaguely that "marsh deer have not been seen active during the night" while Hutchins *et al.* (2003) suggest that the species is mainly nocturnal. Hence the literature on the subject is contradictory.

Studies on the detailed time budget and activity patterns of free-ranging wild ungulates using scan samplings have often been limited by the ability to only collect data during daylight hours (Pépin *et al.* 2006). With GPS collars, as in this study, the marsh deer's activity can be followed 24 hours a day and for several months. This has never been done before for this species.

About the marsh deer (Blastocerus dichotomus)

Morphology

The marsh deer is the largest cervid in South America, with an average shoulder height of 1.3 meters and an average weight of 100 kg for females and 130 kg for males (Figueira *et al.* 2005). Morphologically, the marsh deer is well adapted to wetlands and riverine habitats. It has long, dark legs. The hooves are broad and spatulate, the toes are long and bound together with a strong, elastic membrane, giving them a larger surface to prevent them from sinking into muddy soil (Vrba & Schaller 2000, Pinder & Grosse 1991).

Ecology

The habitat of the marsh deer is marsh areas and seasonally flooded riverine areas. The marsh deer is highly dependent on aquatic vegetation and prefers flooded areas in tropical and subtropical wetlands where the depth of the water is 30-60 cm and with low plant cover. They are grazer-browsers of semi-aquatic species, but grasses and leaves of shrubs are also part of their diet (Pinder & Grosse 1991).

Usually, marsh deer live alone, except for females with their offspring, but may seasonally form groups of up to five individuals. No harem formations have been observed (Pinder & Grosse 1991). Published reports on home range sizes vary greatly for this species ranging from 3 to 33 km^2 in females and from 8 to 64 km^2 in males (Márquez *et al.* 2006).

According to Pinder & Grosse (1991), predation on adult marsh deer by jaguars (*Panthera onca*) and domestic dogs (*Canis lupus familiaris*) has been reported, and wild canids, cats and snakes can prey on the offspring.

Reproduction

Little is known about the mating season of the marsh deer. It is a tropical species with little synchrony in the reproductive patterns over the entire range. In more southern locations mating takes place between October and November, but in more tropical areas it can occur throughout the year. A single offspring is typical at partus (Vrba & Schaller 2000). The gestation period is about 260 days, and the young remain with their mother until the age of about one year. Females mate again soon after giving birth (Hutchins *et al.* 2003).

Distribution and threats

The species has an original range associated to most of the riparian marshlands from south of the Amazon River to northern Argentina (Márquez *et al.* 2006). However, Weber & Gonzalez (2003) estimates that the global distribution of the marsh deer has been reduced with 65% in the last four decades. Its distribution is now very patchy. The species is currently distributed throughout south-eastern Peru, Bolivia, Paraguay, northern Argentina and Brazil to the south of the Amazon rain forest (Márquez *et al.* 2006).

In Brazil, large populations of marsh deer can be observed only in restricted areas of the Pantanal, the Bananal Island region, the Araguaia and Guaporé rivers, and the remaining floodplains of the Paraná River (Figueira *et al.* 2005). The latter population is decreasing in an alarming rate due to recent flooding of the habitat since many hydroelectric dams have been constructed in the area (Weber & Gonzalez 2003). The marsh deer is now placed on the list of Brazilian species threatened with extinction (Figueira *et al.* 2005). It is also classified as vulnerable by the IUCN (Varela *et al.* 2002).

Total population numbers are unknown, but are certainly declining throughout its range (Weber & Gonzalez 2003). The main threats are habitat destruction and fragmentation, historically due to agriculture and cattle grazing. More recently the construction of large hydroelectric dams has become the main cause for the species disappearance, since wide-scale loss of lowland and riparian habitats is an inevitable consequence of such constructions (Figueira *et al.* 2005). Moreover, poaching and diseases transmitted from cattle have been factors contributing to the decline, mostly a threat to populations already small and isolated (Márquez *et al.* 2006).

Background to the study

In São Paulo State, the marsh deer is classified as “critically endangered”. The last relevant population of the species was found on the floodplain of the Paraná River between the dams of Jupiá and Porto Primavera. This area was flooded in 1998 when the Porto Primavera hydroelectric dam was constructed, resulting in the species now being more or less extinct in São Paulo State (Figueira *et al.* 2005).

To be able to conserve this species in São Paulo State, a group of researchers developed the Marsh Deer Reintroduction Project (Projeto de Reintrodução do Cervo-do-Pantanal). The purpose was to reintroduce marsh deer originating from the Porto Primavera population into the remaining floodplains in São Paulo State from which the original population had previously disappeared. In 1998, five radio-collared, adult marsh deer were reintroduced in the Jataí Ecological Station, a protected area managed by the São Paulo Forest Institute, *Instituto Florestal*. Figueira *et al.* (2005) describes the dispersal and spatial preferences of the reintroduced animals during their first 16 months in the new area. In 2006, eight years after the reintroduction, there were about twenty animals in marshlands connected to the Jataí Ecological Station (Duarte, personal communication).

Aim of the study

The aim of my study was to investigate the diurnal, nocturnal and crepuscular behaviour of the reintroduced population of the marsh deer in Jataí by showing how the activity patterns vary over 24 hours and over a longer time period. The particular questions I was interested in answering were the following:

What time of day are the marsh deer in Jataí mostly active, and when are they resting? What are the proportions of activity versus passivity during a 24-hour period? How long are the active and passive periods? How does the activity differ between different months? Are the deer using the same areas at day and night? What are the potential causes of the marsh deer's activity patterns?

Materials and methods

Study area and research group

The Jataí Ecological Station is a protected area managed by the Instituto Florestal, situated in Louis Antonio, São Paolo State (21º33'S/47º45'W and 21º37'S/47º51'W). The study area consists of the floodplains along the Mogi-Guaçú River inside the protected area, and of three privately owned marshes, in connection to Jataí (Figueira *et al.* 2005). The largest and most important of these marshes, which contains the bulk of the reintroduced population, is a private floodplain area named Capão-da Cruz (1,512 ha) at the western border of the Jataí Ecological Station (Duarte, personal communication). Jataí has a total area of 9,010 ha which is covered by cerrado vegetation and a rich aquatic mosaic including lowlands, streams, marginal lagoons, and floodplains (Figueira *et al.* 2005). The entire study area is surrounded by sugarcane plantations, roads and forests.

The researchers behind the Marsh Deer Reintroduction Project, led by J. M. B. Duarte from the department of Animal Technology, University of Jaboticabal, São Paolo, have continuously been recapturing animals from the Jataí-population since the reintroduction. Their purpose has been to monitor the population regularly in order to follow population growth and animal welfare. Samples of hair and blood have been taken for analyses, weight has been estimated and the animals have been tagged for radio surveillance. Such a recapture took place on the 28-29th of October 2006. Therefore, the GPS-collars could be put on the animals without an extra capture occasion. This study was planned and carried out in collaboration with the Brazilian research group.

Two other Swedish students, Josefine Larsson and Josefin Ragge, were participating in this study while conducting their own degree projects with investigations related to the same study animals. Josefine was mapping the deer's habitat by doing an inventory of plants within Andrea's home range while Josefin was analysing the vegetation with the aid of satellite pictures of the study area.

The capture

The deer were captured on the 28-29th of October 2006 with a technique called "Bulldogging" developed solely for this species by Duarte *et al*. Each deer was chased with a helicopter until exhaustion, or for a maximum of ten minutes, whereupon two men jumped off the helicopter onto the deer, wrestling it to the ground. The deer was then held down for about fifteen minutes, allowing a third person to sample blood and hair, to put an ear tag and the GPS-collar on it. Even though this procedure might seem stressful for the animal and therefore unethical, it is considered by the Brazilian research team that developed it to be the least dangerous way to capture the animals. No anaesthesia is used during the procedure due to an otherwise high risk of the deer drowning, since the habitat is wet (Duarte, personal communication).

Study period and climate

Data was collected from the 28th of October 2006 to the 17th of February 2007. The length of the study period differed for the two focal deer. From the collar of one of them, Andrea, we received data only until the 2nd of December 2007, whilst from the collar of Julia data was collected during the entire study period.

The weather during the study period was dry and hot with a more or less constant increase in temperature and precipitation towards the end. The daylight hours did also increase. Figure 1 shows the average temperature and precipitation per month in the city of São Paolo. Jataí is situated about 400 km inland from São Paolo, hence the temperature is higher, but the yearly pattern is similar.

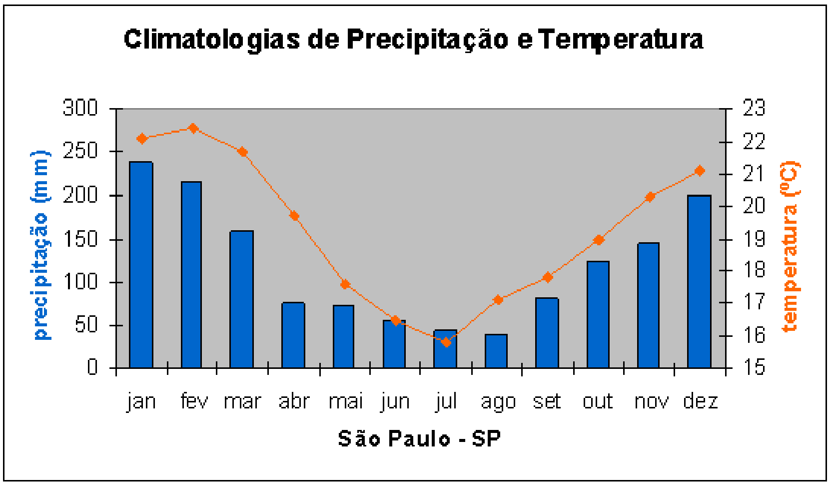

Figure 1. Average monthly precipitation and temperature in São Paolo. (Brazilian Institute of Aerospace Research 2007)

GPS-collars

Three female marsh deer were tagged with GPS collars (Tellus Remote GSM, Televilt, Lindesberg, Sweden). The collars were configured following the Tellus GPS System User Manual (revised Aug 7th, 2006) using TPM software (Televilt, Lindesberg, Sweden). The coordinate system was UTM. The GPS-position of the deer was recorded and stored in the collars with a chosen time interval. An activity measurement, which described the number of changes in collar position during the time it took for the collar to obtain the GPS fix, was also recorded for the same interval.

From two of the deer, named Julia and Bruna, the positions were recorded every five minutes. From the third deer, Andrea, the position was recorded every ten minutes. In addition, an SMS with the GPS points was sent to the Televilt database every 70 minutes. This enabled us to continuously download data points with Andrea's position, hence receive her position just after real time.

The two deer Julia and Bruna were recaptured in July 2007. Julia's collar was then removed and the data was downloaded from the collar. The collar had collected data until it ran out of battery on February 17th, 2007. Bruna had by the time of the capture lost her collar and hence all the data was lost. Andrea has not yet been recaptured and is probably still wearing her collar, but it ran out of battery on December 2nd, 2006 and records no more data. However, her data has been downloaded from the Televilt database, thanks to the SMS-function.

The data set

The data was downloaded either from the Televilt database (when the SMS-function was activated) or directly from the collar after the deer had been recaptured. The data set looked a little bit different in the two cases but the essential information was the same. Table 1 shows an example from the excel-sheet that was downloaded from the GPS collar after the deer Julia had been recaptured and her collar had been removed.

Table 1. Part of Excel-sheet downloaded from the GPS collar of the deer Julia.

Date	Time	TTF	North.	East.	DOP	SVs	X	Y
2006 10 30	06:40:00	62	9979014	460989	0.6	5	0	3
2004 02 00	00:09:00	0	7619912	201733	2.0	5	5	18
2006 10 30	06:50:00	96	7610980	201901	1.9	5	0	0
2006 10 30	06:55:00	40	7610975	201908	1.6	6	0	0
2006 10 30	07:00:00	70	7610983	201900	1.8	6	1	0
2006 10 30	07:05:00	40	7610979	201905	3.7	5	0	0
2006 10 30	07:10:00	45	7610986	201910	2.2	5	0	0
2006 10 30	07:01:00		TimeOut					
2006 10 30	07:23:00		TimeOut					
2006 10 30	07:25:00	39	7610984	201903	2.2	4	0	1
2006 10 30	07:30:00	57	7610983	201901	1.2	6	4	11
2006 10 30	07:35:00	47	7610985	201899	1.2	6	1	1

Below is an explanation of the values in table 1 (Televilt 2006):

Date = the date when the position was obtained (yyyy mm dd).
Time = the time (in GMT) when the GPS receiver was activated in order to attempt a GPS position (hh:mm:ss).
TTF = Time to Fix. The time, in seconds, that the GPS receiver has used to obtain the fix. This time may be used to determine the optimal GPS search time for the collar.
North = the latitude displayed as degrees, decimals.
East = the longitude displayed as degrees, decimals.
DOP = Dilution of Precision, a measure of the quality of the GPS data being received from the satellites. DOP is a mathematical representation for the quality of the GPS position solution. The main factor affecting DOP is the configuration of (distance and angle between) the satellites used to obtain the position. This value may be anything between 0.0 and 25.0. The lower the DOP value is the better the satellite configuration, and presumably the more accurate position. ***However,*** *note that a low DOP value doesn't necessarily give an accurate position.* The accuracy is also dependent on number of satellites to obtain the position. As a general rule, positions that are obtained using many satellites, *and* have a low DOP value are accurate. Positions that have *either* low number of satellites *or* have a high DOP value may not be as accurate.
SVs = Satellite Vehicles. Shows how many satellites are used to obtain the position.
X,Y = Displays level of activity (neck movements). The activity is measured as a certain change in collar position during the time the collar has used to obtained the GPS fix, and is measured every second during the fix attempt. If the animal is inactive, a low number of position changes in the collar position are expected. If the animal is active a higher number of changes during the fix attempt are expected.

Data treatment

The downloaded data files contained many errors and plenty of inaccurate data. The first step in the data treatment was hence to remove any such errors. As shown in figure 2, rows assigned “Time Out” were commonly occurring, denoting that the positions were not fixed within the time limit, and that the position was therefore not recorded. In addition, the data set sometimes contained incorrect date or time recordings, or GPS positions that were way out of the study area. GPS positions could also be obviously wrong in the sense that the deer seemed to have moved a distance of several hundred meters in one direction only to be back at almost exactly the original position five minutes later. All these rows had to be manually deleted from the data set before doing any kind of analyses. In addition, all data registered before the 30^{th} of October was removed, taking into account that the deer’s behaviour might have been affected by stress from being captured during the first few days.

The X and Y measurements were added together to an “activity column”, to receive a measurement of the deer’s total level of neck movements with respect to change of collar position both vertically (X) and horizontally (Y). The activity value varied from 0 to 142, but was in most of the case (> 83 %) between 0 and 10; only less than < 4 % exceeded 20. In order to determine the deer’s activity level the threshold for neck movements (X+Y) had to be set somewhere above 0. Since we had no reference on how to choose these values we analysed the data for three different thresholds: 1, 3 and 5 and compared the different results.

The “Northing” and “Easting” measurements were used to calculate the distance between the deer’s position within each time interval. Each position was subtracted from the position of the previous measurement, resulting in a positive or negative distance for “Northing” and “Easting”. Using Pythagoras’ theorem ($a^2 + b^2 = c^2$), the real distance between the two points was then calculated. However, it cannot be assumed that the deer moved in a straight line. Therefore this procedure did not provide us with information on how many meters the deer has moved but gave us, with the distance between the deer’s position at the two points of measurement, a good indication on how many meters the deer had moved.

In order to correct for inaccuracies in the GPS, the mean of the distance of four measurements was used in the analyses of the data. The cases where the deer appeared to have moved several hundred meters in one direction and five minutes later have returned to the original position were in this way eliminated. For example, an extremely high value in one row would be equalled by a corresponding low value in the next row.

Statistical analyses

The data on activity patterns were pooled for every hour, deer and day before calculating mean values and standard errors (SE). Statistical data were tested with Kruskal-Wallis test.

I tested the degree of linear relationship between the pairs of variables “Distance Nov – Feb” and “Neck movements Nov – Feb” with Pearson’s product moment coefficient of correlation, using MINITAB 14.

Results

Collected data

Between October 25th 2006 and February 17th 2007, I recorded a total of 37527 data points for the two individual deer. After removing the incorrect points (see methods), 36463 were used in the analyses. 4826 points were assigned Andrea, measured from October 30th to December 2nd 2006, and the rest came from Julia's collar, measured from October 30th 2006 to February 17th 2007. The data points from Andrea's collar were recorded every ten minutes, the data points of Julia's every five minutes.

General activity patterns

Figure 2 shows the two deer's activity patterns for the entire study period. The neck movements and the distance between each recorded GPS point are shown as mean values per hour.

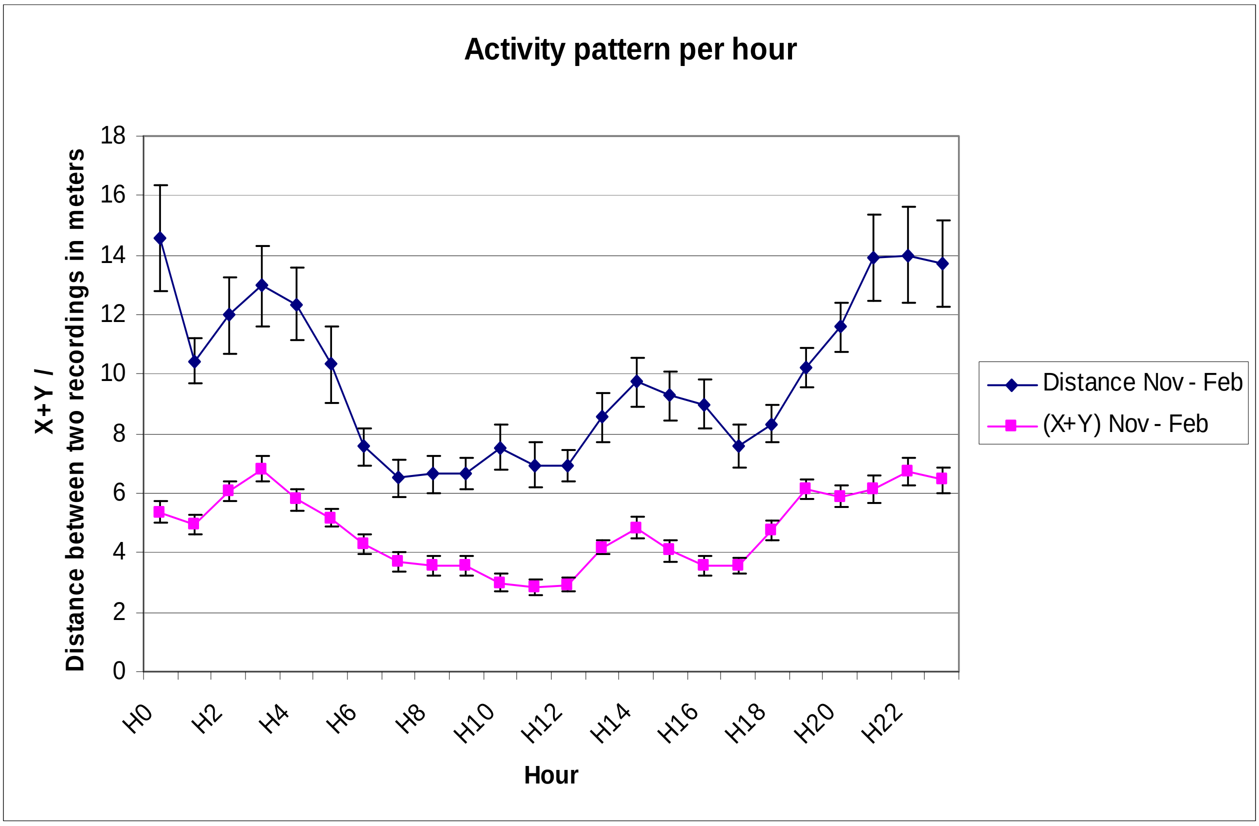

Figure 2. Average distance moved and average neck movements within each time interval per hour. The pink line shows the mean value for neck movements within each recording interval per hour, whereas the blue line shows the mean distance between each recorded GPS position. H0 is the hour between 23:30 and 00:30 local time, H1 between 00:30 and 01:30 etc.

X+ Y is the mean number of neck movements per hour, a number that describes the sum of the changes in collar position both vertically (X) and horizontally (Y).

The activity was higher during the night (18:30-06:30) than during the day (06:30-18:30) for both distance (Kruskal-Wallis, $H = 235.89$, $P < 0.001$) and neck movements (Kruskal-Wallis, $H = 331.55$, $P < 0.001$).

The deer's activity was highest during the dark hours. The distance between the GPS points was highest between 21 hrs until midnight. The distance curve had a dip around 13 hrs, went up again and stayed high until about five in the morning, when it dropped substantially. There was a small peak during the afternoon hours, the curve then went down again around 18 hrs and then increased until 21 hrs. The curve for neck movements followed a similar pattern, with a higher activity at night time than during the day and a peak in the afternoon.

Relationship between neck movements and distance moved

Figure 3, which is a regression analysis of activity versus distance (mean value per hour), shows the extent of correlation between the lines in figure 2.

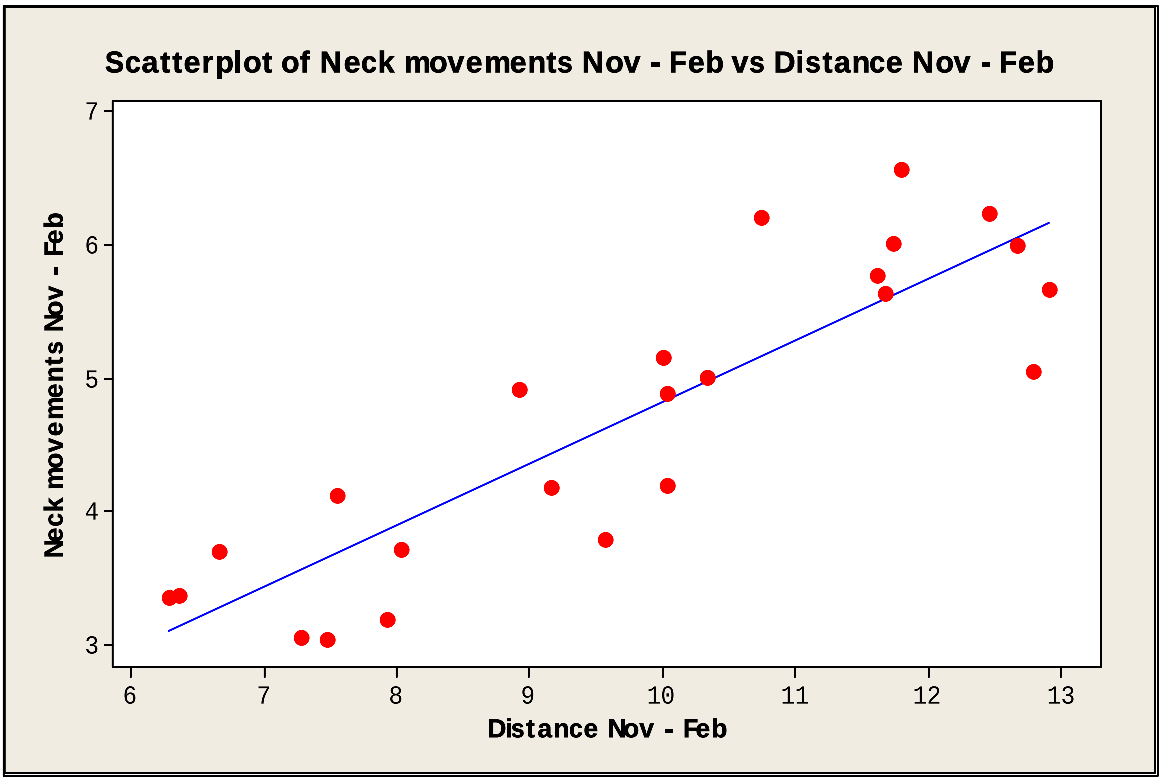

Figure 3. Scatterplot with regression line of neck movements versus distance.
The regression equation is: $y = 0.187 + 0.463 x$, $n = 24$, $p < 0.001$.

The degree of linear relationship between the pairs of variables "Distance Nov – Feb" and "Neck movements Nov – Feb" is significant (Pearson's product moment coefficient of correlation, $r = 0.880$, $P < 0.001$).

Neck movements in different months

To investigate the difference between different months, I separated the study period into two different sections, November-December and January-February. These are shown for activity (Figure 4) and distance (Figure 5) separately.

Figure 4 shows the average activity value within each recording interval. There were no statistical differences between the different months (Kruskal-Wallis, H = 1.09, P = 0.579).

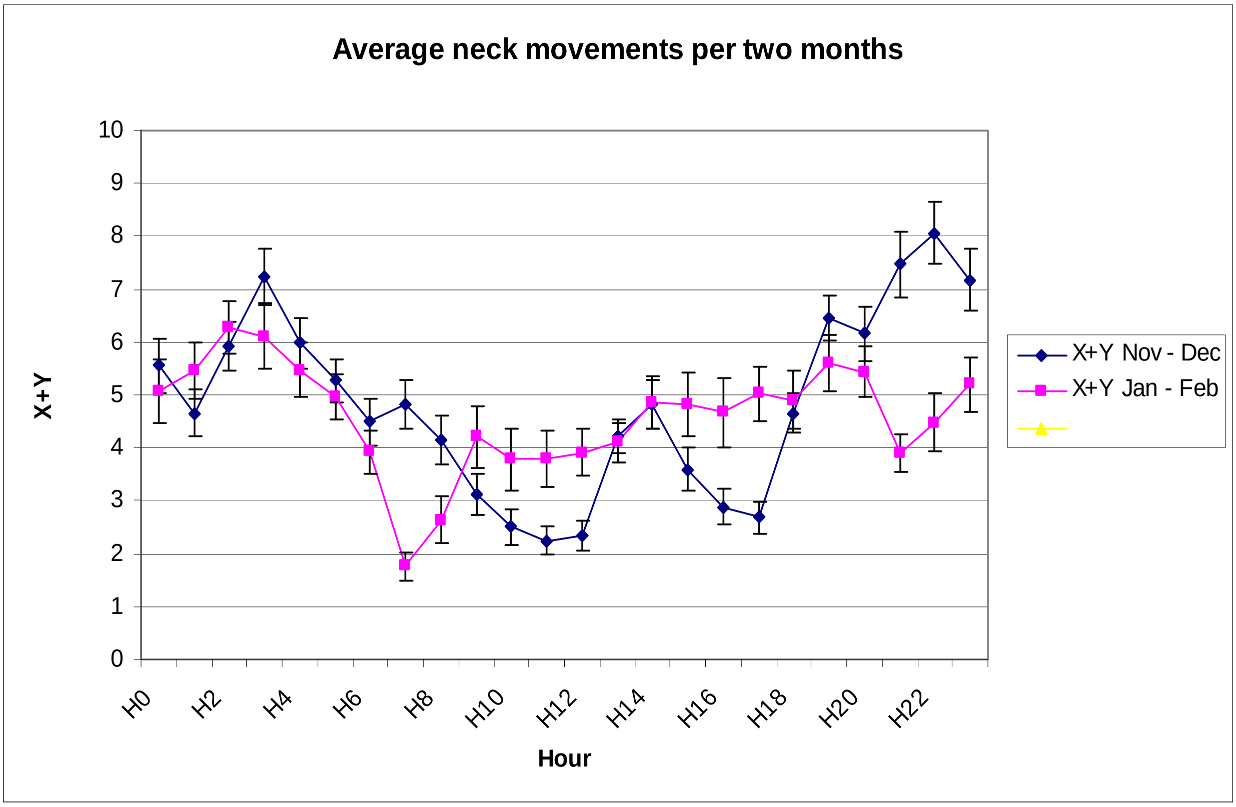

Figure 4. Average neck movements within each time interval per hour, for different months. The blue line shows the mean neck movements within each recording interval in November and December, the pink line in January and February.

Distance moved in different months

In figure 5, the mean distance between two GPS points between two time intervals is illustrated in the same way as in figure 4. There is a difference between the first and the last months, where the deer seemed to have moved more in January-February than in November-December. (Kruskal-Wallis, H = 201.1, P < 0.001).

However, this pattern was only seen between 9 and 21 hrs, where the line for January-February corresponded to substantially higher values for distance than did the line for November-December.

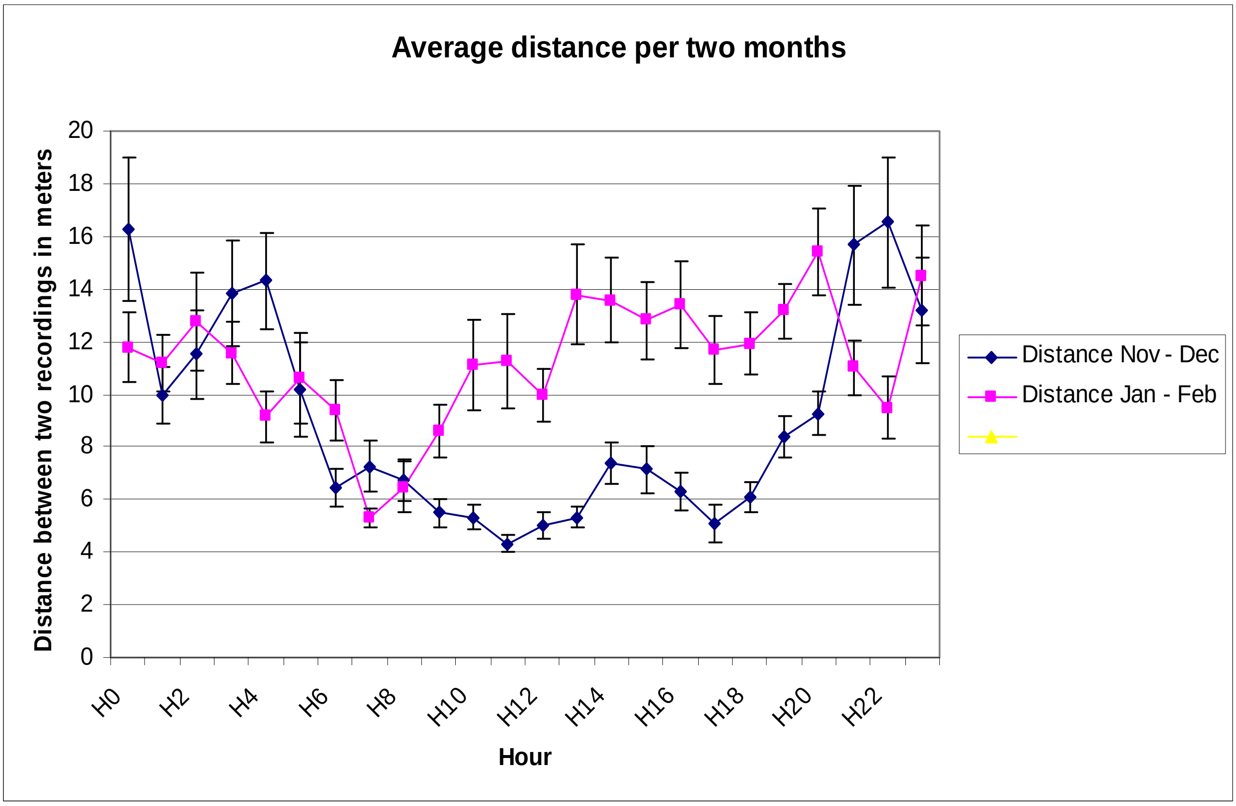

Figure 5. Average distance moved within each time interval per hour, separated per two months. The blue line shows the mean distance between within recording interval in November and December, the pink line in January and February.

Thresholds for neck movements

The relative neck movements is compared for different threshold values (1, 3 and 5) of X+Y in table 2. See "data treatment" for explanations of the values X and Y. The percentage of active and passive data points are shown for both of the deer together and for Andrea and Julia separately.

Table 2. Neck movements in percentage for the entire study period, with different thresholds of X+Y.

Neck movements	Both deer		Andrea		Julia	
	Active	Passive	Active	Passive	Active	Passive
X+Y threshold 1	55%	45%	53%	47%	61%	39%
X+Y threshold 3	42%	58%	42%	58%	49%	51%
X+Y threshold 5	34%	66%	35%	65%	43%	57%

The percentage of activity for both of the deer varied from 34% to 55% depending on the threshold value chosen. There was also a difference between the two deer, implying that Julia had a generally higher level of neck movements than Andrea. However, Julia's contribution to the mean values is higher than Andrea's since the data set was larger in her case. Because of this, the values in the column "both deer" is not exactly in between the values of the two deer.

Diurnal and nocturnal habitat use

The average GPS positions for day and night are illustrated with different colours in figure 6, where the black circles represent day (06:30-18:30) and the red squares represent night (18:30-06:30). The x- and y-axis represent the coordinate system of the deer's habitat (not according to scale). There appears to be no obvious difference between day and night.

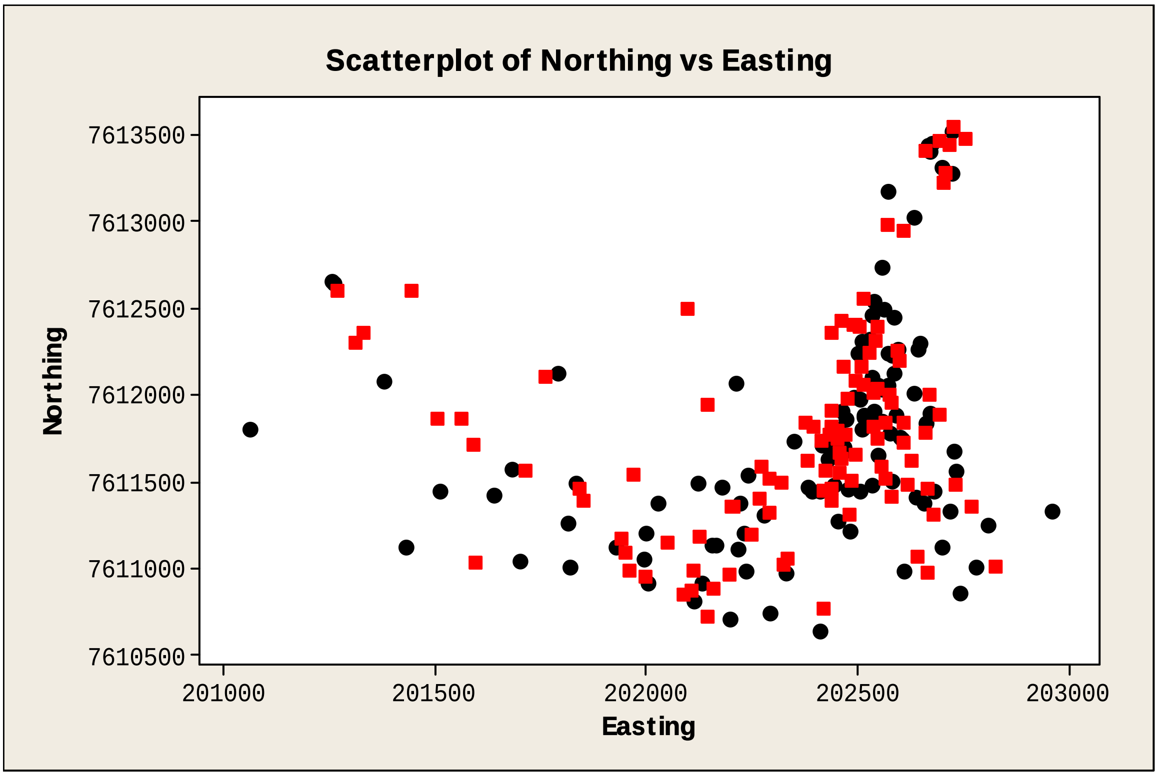

Figure 6. Scatterplot of the mean values of the deer's average position per hour during day (black circles) and night (red squares).

Discussion

The marsh deer in this study were primarily nocturnal, according to the activity patterns for both distance and neck movements in figure 2. Some diurnal activity was seen, especially in the afternoon, while activity at dusk and dawn was low. This pattern contrasts the common opinion that most wild ungulates are active in the early morning and late afternoon (Leuthold 1977). What are the underlying evolutionary factors that determine the marsh deer's activity patterns? Are ecological factors like predation pressure or food abundance the most important, or is it environmental conditions like temperature and weather that matter most?

First, I will look into the activity patterns of other deer species, in South America and elsewhere. I will also go through the possible predators of the marsh deer to try to find out how these could have influenced the deer's behaviour. Environmental and other ecological conditions will also be taken into account before any conclusions can be drawn.

Activity patterns in other deer species

Pampas deer (*Ozotoceros bezoarticus)* have been found having both diurnal and nocturnal activity periods in the Emas National Park and in the cerrados (Brazilian savannas) of Brasília, Central Brazil. (Rodrigues & Monteiro-Filho 2000) White-tailed deer (*Odocoileus virginianus*) studied in Texas were most active in the morning and evening (Jackson *et al.* 1972).

A study by Rivero *et al.* (2005) on two sympatric brocket deer species in Bolivia showed that red brockets (*Mazama americana*) were active mostly from sunset until sunrise (6 p.m. to 6 a.m.) and gray brockets (*Mazama gouazoubira*) mostly in the morning (5 a.m. to 10 a.m.).

Among red deer (*Cervus elaphus*) in Europe, daily activity is generally influenced by cycles of light and darkness, with bimodal peaks in activity coinciding with dusk and dawn (Kamler *et al.* 2007). Moose and roe deer studied in Sweden were most active during sunrise and sunset (Cederlund 1989).

A study by Taylor *et al.* (2006) on grey rhebok (*Pelea capreolus*) and southern mountain reedbuck (*Redunca fulvorufula fulvorufula*) two sympatric antelope species in South Africa, showed that both species spent more time feeding in the late afternoon during relatively cool temperatures and more time resting in the middle of the day during relatively high temperatures. Bushbuck (*Tragelaphus scriptus*) in Uganda was found by Wronski *et al.* (2006) to show peak activities around sunrise and at dawn. No difference in the mean activity rates was found between the dry and wet season.

The only deer species I have found in the literature with a nocturnal pattern similar to the marsh deer's was the red brocket deer. Red brocket and marsh deer have largely overlapping distribution ranges (Weber & Gonzalez 2003), which could denote that the underlying factors to the two species' activity patterns are of the same kind.

Predators

Predation risk is an important evolutionary explanation to different activity patterns in animals (Halle & Stenseth 2000). I will therefore look closer into the feeding ecology of some possible predators upon marsh deer, in Jataí and elsewhere.

Jaguars are known to be nocturnal, but have also shown considerable activity during dawn and dusk (Weckel *et al.* 2006). As mentioned earlier, jaguars have a record of preying on marsh deer. Even though there are no jaguars left in Jataí, the two species coexist in several places and have done so to a large extent in a historical perspective (Hutchins *et al*. 2003; Weber & Gonzalez 2003). The jaguar could therefore have an important evolutionary effect on the marsh deer's behaviour, being the largest felid in South America.

The maned wolf (*Chrysocyon brachyurus*) is a mainly nocturnal and crepuscular species, but has been shown to be active during the day in some areas of Brazil (Bandeira de Melo *et al.* 2007). This species normally takes smaller prey (Hutchins *et al.* 2003), but could be a possible predator upon mars deer fawns. The maned wolf is commonly occurring in the study area (Duarte, personal communication).

Puma (*Felis concolor*) and ocelot (*Leopardus pardalis*) are both nocturnal cats (Hutchins *et al.* 2003); their distributions overlap with the marsh deer's. Ocelot is strongly nocturnal (Di Bitetti *et al.* 2006), while puma also exhibits activity peaks at dusk and dawn. Puma is known to prey on deer, while ocelot takes smaller prey (Hutchins *et al.* 2003). Puma exists in Jataí (Duarte, personal communication).

Another predator commonly occurring in the marshes of Jataí and other marsh deer localities (Duarte, personal communication) and which is known to prey on deer (Martins & Oliveira 1999), is the green anaconda (*Eunectes murinus*). Literature indicates that the anaconda is a nocturnal species (Martins & Oliveira 1999).

As mentioned earlier, there have been reports of domestic dogs taking marsh deer (Pinder & Grosse 1991). There are very few houses in and around Jataí, but there is a farm nearby and with the village Louis Antonio situated about 10 kilometres away there could be some strolling dogs in the area. Dogs have in general both diurnal and nocturnal activity (Adams & Johnson 1993).

This overview of possible predators tells us that they are all more or less nocturnal, except from the domestic dog. If the predator pressure were to be the main factor influencing marsh deer activity patterns, my results would be inconsistent with these data. An exception is the result that the marsh deer in my study had a low crepuscular activity, which could be an adaptation to the high activity of the large felines jaguar and puma, possibly even maned wolves, at dusk and dawn.

On the whole, in order to avoid predators, the marsh deer would probably be better off having diurnal activity and hiding at night. My conclusion from this is that the main cause of the marsh deer's nocturnal activity probably is to be found elsewhere.

Environmental factors

Could the low diurnal activity of the studied deer be an effect of the high temperatures during the day? Studies on behavioural thermoregulation in ungulates have shown reduced activity and increased resting in browsing ruminant species on days with high maximum temperatures (du Toit & Yetman 2005). This suggests that the studied deer rest during the day and do most of their foraging at night when temperatures are lower. I presume that temperature change during the course of a 24-hour period is an important factor of the deer's activity pattern. It would be interesting to find out what the diurnal behaviour looks like during the dry season when temperatures are lower.

Both temperature and precipitation increased towards the end of the study period. The deer seemed to have moved more during the day in January-February than in November-December, in spite of the rising temperatures. This is a bit contradictory to the theory that it rests during the day because of hot weather. Also, daylight hours increased towards the end of the study period. This means that dusk and dawn occured earlier and later, respectively, which could be a possible explanation to increased daytime activity. If the nights were shorter and the deer still avoided being active at dusk and dawn, would it have been "forced" to be more active at daytime to forage? It has been shown for red deer in Germany that the relative height of the crepuscular peaks decreased in the summer months in favour of more activity during the daylight hours (Georgii 1980).

The body size of the marsh deer is, with its 100-130 kg, larger than in other South American deer. White-tailed deer weighs 50-120 kg, pampas deer weighs about 40 kg and brocket deer is even smaller (Vrba & Schaller 2000). As mentioned earlier, a large herbivore requires in theory less rest than a small one, and the activity bouts are generally longer. Moreover, a large herbivore has lower demands on food quality. They spend less time foraging but more time eating (du Toit & Yetman 2005). This would suggest that the marsh deer could have a higher activity than smaller deer species with overlapping habitats, for example brocket deer. To test whether this is true, the other species would have to be studied with the same methods and the activity data compared.

The marsh deer feeds on grasses and shrubs, but aquatic reeds are also an important part of the diet (Tomas & Salis 2001). Aquatic plants are in general more easily digested than grasses and shrubs, which in theory would make the resting periods shorter for a consumer of these plants. Also, a grazer generally spends less time ruminating than a browser (Taylor *et al.* 2006). The composition of plants in the marsh deer's diet could therefore have a possible effect on the activity patterns.

The marsh deer population in Jataí is growing on a quite small area. The floodplains inside the protected area and the private Capão-da-Cruz floodplain together total an area of about 20.5 km^2 (Márquez *et al.* 2006). The possibilities of dispersal to other localities are very limited, since most of the adjacent land is used for agriculture. At what population density will the competition be too hard? Records of population densities vary from 0.05 to 0.524 individuals per km^2 (Vrba & Schaller 2000), implying that the species is flexible and that there still is room for more individuals in the area. How will the activity patterns of marsh deer in the study area be affected if and when competition of resources increases? My guess is that home-range sizes will decrease and therefore also movements within the area. However, the effect on every day patterns is more difficult to predict. Scarcity of food resources could possibly force the deer to be active a larger proportion of the day to forage.

Human influence

Historically, there has been a large hunting pressure on marsh deer for meat and skin (Pinder & Grosse 1991). Could the fear of humans, who are mostly hunting during the day, have affected the activity patterns of this species? There are records of deer species having changed their activity patterns due to hunting pressure (Georgii 1981). In Jataí, the deer is currently not hunted, but human disturbance just outside the marsh is still quite high. The study area is surrounded by small roads with a truck passing now and then. There is an ethanol plant nearby and plenty of agriculture activity is going on in the area due to the sugarcane plantations. The capture of deer with the aid of a helicopter described earlier is taking place several times a year and it is unknown what impact these events have on the population.

The study animals

The studied animals were both female. I choose to tag only females to be able to get less variation in the data; differences in behaviour between male and female marsh deer have been recorded. As mentioned earlier, home range sizes are in general substantially larger in males (Márquez *et al.* 2006). This suggests that my results for distance moved per time interval and hour could have differed if I had studied males instead of females. I also wanted to minimise the risk that focal animals would leave the study area, which I assessed as higher in males.

Since my sample size is so small, and I only studied females, it is uncertain to draw conclusions from my results about the population in general and even more so about the entire species. However, since this is the first study in activity patterns in this threatened species, I consider my results still as very useful to understand the behaviour of this species.

Interpretation of results

I suggest that increased neck activities without moving many meters are an indication of grazing behaviour. If so, the results in figure 4 and 5 could be interpreted as follows: The grazing behaviour did not change with the seasons, but the deer was moving around more on the latter half of the study period, as the temperature and humidity rose. That is consistent with results from a study by Rodrigues & Montheiro-Filho (2000), which showed a higher movement of pampas deer in the rainy season. However, these results should be interpreted with cautiousness, since I only had data from one individual in January, February and most of December.

Ethical considerations

As mentioned earlier, the capturing technique called "bulldogging" could be considered as stressful for the animals. There are no investigations made on this subject. However, there is no other known suitable method on how to capture this species (Duarte, personal communication). There is also the aspect of collars and possible hazard they might give to the animals. For any animal tagged with a collar there is a risk of getting stuck and becoming injured. There is also a risk of neck lesions from the collar itself (Krausman *et al.* 2004).

One could argue that research is essential in order to find out how to best conserve this species, and that a small amount of stress to the animals therefore can be justified.

Obviously, this is the opinion of research group in Jataí since they have used this method for many years.

Suggestions for further studies

My study is revealing several important factors on activity patterns of the marsh deer. However, it is limited in many aspects, due to the low sample size and relatively short sample period. Therefore, it should be considered as a pilot study, with the advantages of testing a technique which might be useful to further studies on this and other species.

With a larger sample size and a study period of one or several years, I could draw conclusions on the population's activity patterns throughout all seasons. Differences in diurnal, nocturnal and crepuscular use of the habitat over different seasons, as well as variations in home range sizes could be detected. Furthermore, it would be interesting to study the deer's activity pattern related to reproductive behaviour. A comparison with data on the deer's diet, food abundance and food quality at different time of the year would also be informative.

The proportion of activity during a day is highly dependent on the threshold value chosen for neck movements. In order to determine which threshold is the most suitable for the species, it would be useful to test this in advance. A way to do this would be to put collars on deer in captivity, perform an observational study and compare the resulting data with the collar data.

Conclusions

The marsh deer in this study were primarily nocturnal, although some diurnal activity was seen, especially in the afternoon. Crepuscular activity was low.

Activity measured as neck movements did not differ between different months for our study animals. On the other hand, there was a change in the distance that the deer had moved per time interval, which increased towards the end of the study period. My conclusion is that weather conditions probably have a large influence on activity patterns. Predator pressure could also play an evolutionary role for the diurnal, nocturnal and crepuscular activity of the marsh deer.

There were individual differences in the percentage of total activity for the two deer. The threshold value chosen for activity is important to receive reliable results, and this needs to be tested in advance.

Acknowledgements

I would like to thank my supervisor Jens Jung, my co-workers Josefine Larsson and Josefin Ragge and all the Brazilians who made this study possible: Mauricio, Mateus, Alexandre, Alisio, Kena, Marco, Marcel, Evelyne, Sebastião, Vera and Elias.

References

Adams, G. J. & Johnson, K. G. 1993. Sleep–wake cycles and other night-time behaviors of the domestic dog *Canis familiaris*. *Applied Animal Behaviour Science,* 36: 233–248.

Bandeira de Melo, L. F., Lima Sábato, M. A., Vaz Magni, E. M., Young, R. J. & C. M. Coelho, C. M. 2007. Secret lives of maned wolves (*Chrysocyon brachyurus* Illiger 1815): as revealed by GPS tracking collars. *Journal of Zoology,* 271: 27–36.

Cederlund, G. 1989. Activity patterns in moose and roe deer in a north boreal forest. *Holarctic Ecology*. 12: 39-45.

Di Bitetti, M. S., Paviolo, A. & De Angelo, C. 2006. Density, habitat use and activity patterns of ocelots (*Leopardus pardalis*) in the Atlantic Forest of Misiones, Argentina. *Journal of Zoology*, 270: 153–163

du Toit, J. T. & Yetman, C. A. 2005. Effects of body size on the diurnal activity budgets of African browsing ruminants. *Oecologia,* 143: 317–325.

Figueira, C. J. M., Pires, J. S. R., Andriolo, A., Costa, M. J. R. P. & Duarte, J. M. B. 2005. Marsh deer (*Blastocerus dichotomus*) reintroduction in the Jataí Ecological Station (Luís Antônio, SP): Spatial preferences. *Braz. J. Biol*., 65(2): 263-270.

Georgii, B. 1981. Activity Patterns of Female Red Deer *(Cervus elaphus L.)* in the Alps. *Oecologia (Berl),* 49:127-136.

Halle, S. & Stenseth, S. N. 2000. Activity Patterns in Small Mammals. An Ecological Approach. Ecological Studies 141. Springer.

Hutchins, M., Geist, V., Kleimain, D. G. & McDade, M. C. 2003. Grzimek's Animal Life Encyclopedia, 2nd edition. Volume 14 (Mammals III): 282, 382-383 and 386. Volume 15 (Mammals IV): 391-392. Farmington Hills.

Jackson, R. M., White, M. & Knowlton, F. F. 1972. Activity Patterns of Young White-Tailed Deer Fawns in South Texas. *Ecology*, 53: 262-270.

Kamler, J. F., Jxdrzejewska, B. & Jxdrzejewski, W. 2007. Activity patterns of red deer in Białowieża National Park, Poland. *Journal of Mammalogy*, 88(2): 508–514.

Krausman, P. R., Bleich, V. C., Cain III, J. W., Stephenson, T. R., DeYoung, D. W., McGrath, P. W., Swift, P. K., Pierce, B. M. & Jansen, B. D. 2004. From the Field: Neck lesions in ungulates from collars incorporating satellite technology. *Wildlife Society Bulletin*, 32(3): 987–991.

Leuthold, W. 1977. African Ungulates. A comparative review of their ethology and behavioural ecology. Springer-Verlag.

Márquez, A., Maldonado, J. E., González, S., Beccaceci, M. D., Garcia, J. E. & Duarte, J. M. B. 2006. Phylogeography and Pleistocene demographic history of the endangered marsh deer (*Blastocerus dichotomus*) from the Río de la Plata Basin. *Conservation Genetics,* 7:563–575.

Martins, M. & Oliveira, M. E. 1999. Natural history of snakes in forests in the Manaus region, Central Amazonia, Brazil. *Herpetological Natural History* 6(2):78-150.

Pinder, L. 1996. Marsh deer (*Blastocerus dichotomus*) population estimate in the Paraná river, Brazil. *Biol. Conservation, 75*: 87-91.

Pinder, L. & Grosse, A. P. 1991. Blastocerus dichotomus. *Mammalian Species.* 380: 1–4.

Rivero, K., Rumiz, D. I. & Taber, A. B. 2005. Differential habitat use by two sympatric brocket deer species (*Mazama americana* and *M. gouazoubira*) in a seasonal Chiquitano forest of Bolivia. *Mammalia*, 69: 169-183.

Rodrigues, F. H. G. & E. L. A. Monteiro-Filho. 2000. Home range and activity patterns of Pampas deer in Emas National Park, Brazil. *Journal of Mammalogy*, 81(4):1136–1142.

Taylor, W. A., Skinner, J. D. & Krecek, R. C. 2006. The activity budgets and activity patterns of sympatric grey rhebok and mountain reedbuck in a highveld grassland area of South Africa. *African Journal of Ecology*, 44: 431–437.

Televilt. TVP Positioning AB. Tellus GPS system. *Closer to wildlife*. User Manual, revised August 7, 2006.

Tomas, W. M. & Salis, S. M. 2001. Diet of the marsh deer (*Blastocerus dichotomus*) in the Pantanal wetland, Brazil. *Studies on Neotropical Fauna and Environment*. 36: 9-13.

Vrba, E. & Schaller, G. B. 2000. Antilopes, deer and relatives. Fossil record, behavioural ecology, systematics and conservation. Yale University Press.

Weber, M. & González, S. 2003. Latin American deer diversity and conservation: A review on status and distributions. *Ecoscience*, 10, 443–454.

Weckel, M., Giuliano, W. & Silver, S. 2006. Jaguar (*Panthera onca*) feeding ecology: distribution of predator and prey through time and space. *Journal of Zoology*. 270: 25–30.

Wronski, T., Apio, A. & Plath, M. 2006. Activity patterns of bushbuck (*Tragelaphus scriptus*)
in Queen Elizabeth National Park. *Behavioural Processes,* 73: 333–341.

Internet

Brazilian Institute of Aerospace Research - Weather Forecast Department. http://www.cptec.inpe.br/clima/monit/monitor_brasil.shtml. Downloaded on the 23rd of November 2007.

Varela, D., Piovezan, U., Beccaceci, M.D. & Garcia, J.E. 2002. *Blastocerus dichotomus*. In: IUCN 2007. *2007 IUCN Red List of Threatened Species.* http://www.iucnredlist.org. Downloaded on the 3rd of December 2007.

Personal communication

J. M. B. Duarte. Departamento de Zootecnia, FCAV/UNESP, Via de Acceso Prof. Paulo Donato Castellane s/n, 14884-900, Jaboticabal, São Paolo, Brazil.