Diploma thesis

Social Organization and Habitat Use of the Giant Anteater (*Myrmecophaga tridactyla* L., 1758) in Timber Plantations in Northern Brazil

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ABSTRACT

Tree plantations cover extensive parts of the world’s land surface. The combined global area of timber plantations increased from 130 million hectares in 1996 to 192 million hectares in 2006, corresponding to a growth of 48% in ten years. With this growing extent, the need for conserving biodiversity within these landscapes is increasingly recognized. Many plantation forest managers are adhering to sustainable management guidelines such as those of the Forest Stewardship Council (FSC).

This study was conducted in FSC managed timber plantations of Acacia mangium and the surrounding landscape in northern Brazil. Habitat use and social organization of the giant anteater (Myrmecophaga tridactyla) was determined. A part of the plantation was observed from a vehicle and animals located were followed and behavioural observations conducted. Giant anteaters occurred in outstandingly high densities and showed a marked preference for the plantations. The natural savanna habitat was hardly used. Riparian areas situated directly adjacent to the plantation seemed to provide important refuges for giant anteaters and other mammals. The home ranges of the animals were extremely small and overlapped each other extensively. No spatial territoriality was observed. The animals appeared to avoid conspecífics through a temporal organization that might be managed by means of an olfactory system with scent-marked trees and latrines.

Feeding signs of giant anteaters were sampled to determine the diet within the plantation. 39% termites, 60% ants and on one occasion small reptile eggs were collected at the signs.

The study showed that sustainably managed plantations of Acacia mangium are suitable habitats for giant anteaters. Further studies should determine the influence the plantations have on the remaining native biota of the North Brazilian savanna. Radio tracking of giant anteaters should be undertaken in this region for a more detailed determination of their social organization.

An additional one month study was conducted at the Dortmund Zoo in Germany. A new form of outdoor enclosure was designed on the basis of field data and behavioural observations of captive animals.
ZUSAMMENFASSUNG


Die Ameisenbären hatten, verglichen mit Werten aus der Literatur, sehr kleine Streifgebiete die sich gegenseitig zu großen Teilen überlappten. Räumliche Territorialität unter den solitären Tieren konnte nicht festgestellt werden. Vielmehr scheinen sie Begegnungen mit Artgenossen mithilfe einer zeitlich organisierten
Raumnutzung zu meiden, die eventuell durch Duftmarken an Bäumen und dem Gebrauch von Latrinen aufrechterhalten wird.


Mit der Studie konnte gezeigt werden, dass nachhaltig bewirtschaftete *Acacia mangium* Plantagen durchaus als Habitat für Große Ameisenbären geeignet sind. Weitere Studien sollten unbedingt die Auswirkungen der Aufforstung nordbrasilianischer Savannen mit Akazienplantagen auf die übrige Fauna untersuchen. Weiterhin sollte in dieser Region eine Studie angestrebt werden, in der Bewegungsmuster und die soziale Organisation von Großen Ameisenbären im künstlichen Plantagen Habitat mithilfe von Radiotelemetrie langfristiger und großräumiger verfolgt werden als es in dieser Studie möglich war.

Im Zuge dieser Studie wurde eine einmonatige Untersuchung des Verhaltens Großer Ameisenbären im Zoo in Dortmund durchgeführt und die Ergebnisse aus dem Freiland letztendlich mit den Beobachtungen aus dem Zoo zu einem neuen Konzept der Gehegegestaltung Großer Ameisenbären verbunden. Hierbei wird unter anderem empfohlen, Gehege in Zukunft mit hochgewachsenen Bäumen auszustatten, so dass ein geschlossenes Kronendach dem Tier Schutz bietet.
RESUMO

O presente estudo foi realizado no norte do Brasil, em plantios da espécie Acacia mangium, certificadas pelo FSC (Forest Stewardship Council) e na paisagem circunvizinha.

Foram pesquisados, o uso do habitat e a organização social do tamanduá bandeira (Myrmecophaga tridactyla), um grande mamífero especializado.

Parte das observações, realizadas nas áreas de plantio, foram feitas com a utilização de automóveis, sendo que os animais encontrados foram perseguidos para a realização de observações acerca do seu comportamento.

A incidência dos tamanduás nas áreas de estudo foi extremamente alta e eles mostraram preferência obvia por esta área. O habitat natural de savana foi praticamente não utilizado. As áreas ripárias, situadas nas áreas adjacentes aos plantios, aparentemente, forneceram refúgios importantes para o tamanduá bandeira e outros mamíferos. As áreas de atuação dos animais eram extremamente pequenas, com aproximadamente 135 hectares, sobrepondo-se até 95%. Nenhuma territorialidade espacial foi observada. Os animais aparentemente evitaram a presença de outros, com ajuda de uma organização temporal supostamente controlada por meio de um sistema olfatório, através de demarcação de árvores e de utilização de latrinas.

Para determinar a dieta do tamanduá bandeira foram investigadas as marcas de alimentação do animal em ninhos de insetos sociais. Os animais consumiram 39% de cupins, 60% de formigas como também ocasionalmente ovos de pequenos répteis.

O estudo mostrou que as plantações de Acacia mangium manejadas de forma sustentável podem criar um habitat apropriado para o tamanduá bandeira.

Para a continuação de pesquisa propom-se enfocar o esclarecimento da influência das plantações para o restante do bioma de savana brasileira do norte. Um monitoramento do tamanduá bandeira com equipamento de telemetria deve ser executado nesta região para pesquisar mais a sua organização social.

Durante um mês foi efetuado um estudo adicional no jardim zoológico de Dortmund na Alemanha. Baseado em dados de campo e observações de comportamento no zoológico junto à experiência no ambiente dos plantios foi projetado um novo modelo de cativeiro com para o tamanduá bandeira.
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INTRODUCTION

Giant anteaters (*Myrmecophaga tridactyla* L., 1758) are charismatic mammals with a neo-tropical distribution from Belize to southern Brazil and northern Argentina (Wetzel 1985). Belonging to the family of anteaters (*Myrmecophagidae*) they form, together with sloths (*Bradypodidae*) and armadillos (*Dasypodidae*), the order of Xenarthra, an ancient group of highly specialized mammals that diverged before the differentiation of most mammalian orders and that characterize the fauna of Southern America (Wetzel 1985, Delsuc et al. 2001).

With a body length of 1.0 to 1.2 meters and a bushy tail with a length of up to 0.9 meters, the giant anteater is the largest representative of its order (Nowak 1991). The animal lacks any obvious sexual dimorphism and has long thick fur except on its head and chest, where the fur is considerably shorter (pers. observation, Camilo-Alves & Mourão 2006). Giant anteaters are dark brown with white fore legs and a characteristic black and white stripe that reaches from the breast up to the flanks of the animal (fig. 1). The stripe is assumed to play a role in camouflage: Female anteaters carry their cubs for up to nine months on their back and the stripe of mother and young merge, blurring the contours of the cub (Krumbiegel, 1966).

The massive claws on the fore limbs of the animal are a homologous feature of all extant Xenarthra. While the most Xenarthra are arboreal and use their claws for climbing, the giant anteater is terrestrial. It uses its claws for foraging and folds them into a "skin pocket" when walking (fig. 2, Taylor 1985). This "knuckle walking" is supposed to have evolved as an adaptation to terrestrial quadrupedism (Orr 2005).

Xenarthra means "strange joints". The name arises as the vertebral joints of the animals of this order have additional atypical articulations (Engelmann 1985, Delsuc et al. 2001) which allow them a higher flexibility of the backbone. Because of this anatomical peculiarity, the giant anteaters can switch to an effective bipedal locomotion, a capability they apply during digging, feeding and defence (Wetzel 1985).

The giant anteater occurs in very different habitat types from rainforest to savanna and swamp (Wetzel 1982, Wetzel 1985). Nevertheless, it is assumed to be one of the most specialized mammalian predators, due to its diet consisting of ground dwelling ants and termites (Redford 1985, Redford 1986). The animal shows numerous adaptations to its food habits. The sharp claws are used to dig for social insects or to
Part I Introdution

break open termite mounts (Young et al. 2003), the elongated toothless snout and the slender, long and sticky tongue enable the anteater to consume large amounts (up to 30,000 per day) of insects out of the opened nests (fig. 2, Naples 1999, Montgomery 1985). Auditory and visual senses are rather limited, but an excellent olfactory sense facilitates foraging (Mc Adam & Way 1967, Montgomery & Lubin 1977).

Fig. 1: Giant anteater on a road next to plantations of *Acacia mangium* in Northern Brazil.

Fig. 2: Fore limb of a giant anteater, showing the “skin-pocket” in which the claws are folded when the animal walks.
All previous studies about giant anteaters were conducted in open savanna habitats and several of these dealt with the food habits of the animals (Montgomery & Lubin 1977, Montgomery 1985, Redford 1985 and 1986, Shaw and et al. 1985). The proportion of ants and termites consumed showed strong geographical variation among the studies with anteaters consuming mostly ants in the llanos in Venezuela (Montgomery 1985) and exclusively termites in north-eastern Brazil (Redford 1986). Only a few reports exist about free-ranging anteaters consuming other prey items like beetle larvae or millipedes (Krieg 1944, Shaw et al. 1985). There are as well reports about anteaters foraging at beehives; however there is no certainty whether the animals consumed the insects or their honey (Miranda et al. 2003). In zoos the animals are fed with a mixture of dog food, oat flakes, turf, cream and fruits. Zookeepers have reported that they sometimes additionally consume small vertebrates like mice or fledgling birds, especially during pregnancy (pers. comm. Ilona Offhaus, Dortmund Zoo).

Despite their relatively large body mass of 31 to 45kg (Silveira 1969), giant anteaters have a very low metabolic rate (30% of expected rates, McNab 1985) due to their diet in the wild consisting of prey with low caloric content (McNab 2000). The long, thick fur is presumed to function as effective insulation with low thermal conductivity. The bushy tail is used as a cover during sleeping which provides the animal with further thermal insulation as well as functioning as additional camouflage. These adaptations allow the giant anteater to have a region of thermo neutrality of between 15°C and 36°C while most other ant eating specialists have a much lower thermo neutral range (McNab 1984).

Giant Anteaters are popular animals in zoos all around the world. Nevertheless little is known about the natural behaviour of the animals (Young et al. 2003; Shaw et al. 1987). Only a few studies have dealt with home range size, social organization (Medri & Mourão 2005, Montgomery 1985, Shaw et. al. 1987), activity patterns (Montgomery & Lubin 1977, Camilo-Alves & Mourão 2006, Mourão & Medri 2007) and habitat use (Montgomery 1985, Shaw et. al. 1985, Medri & Mourão 2005).

Giant anteaters are known to be generally solitary animals except for females with young or for short intervals during courtship (Shaw et al. 1987). Home range sizes show geographical variation ranging from a minimum of 270 ± 124 ha in the Serra da Canastra National Park in Brazil (Shaw et al. 1987) to a maximum of 2,500 ha in the
Ilanos in Venezuela (Montgomery 1985). In all studies a certain degree of overlap between home ranges of individual giant anteaters could be determined.

Activity patterns varied remarkably in the different studies. In Venezuela the giant anteaters engaged in nocturnal activity (Montgomery & Lubin 1977) while Shaw found them to be partially diurnal in the Serra da Canastra National Park (1987). Recently, some new studies were publicised that deal with activity patterns in relation to time and weather conditions (Camilo-Alves & Mourão 2006, Mourão & Medri 2007). These studies show that as well as time of day, the ambient temperature plays an important role in the activity patterns of the animals, which are less active on cold days.

In determining habitat feature use it has been shown that the animals show preferences for more closed habitats like gallery forest and forest patches when resting (Camilo-Alves & Mourão 2006, Medri & Mourão 2005, Shaw et al. 1987). Camilo-Alves & Mourão also showed that there was a marked relationship between ambient temperature and the preferred resting habitat: On very cold (<17°C) or very hot days anteaters used forest patches more frequently for resting, presumably to shelter from the wind or the sun. The relationship between habitat use and ambient temperature was weaker during periods of activity and it is assumed that during foraging habitat choice is strongly related to prey availability.

The giant anteater is listed as “near threatened” on the IUCN Red List of species (IUCN 2007), as vulnerable in Brazil by the Ministério do Meio Ambiente (MMA) and on appendix 2 by the Convention on International Trade in Endangered Species of Wild Flora and Fauna (CITES). It is very common in certain parts of its distribution area such as the Serra da Canastra National Park in Brazil (Shaw et al. 1987) or the Boa Vista plains in the State of Roraima in Brazil (Kreutz 2007). However, in most parts of its distribution area there has been an alarming population decline (Miranda 2004) and local extinction in Uruguay (Fallabrino & Castineira 2006). Increasing numbers of bushfires of anthropogenic origin, road kills and hunting have been given as reasons for the decline, though virtually no studies exist (Leeuwenberg 1997). There are no studies to have evaluated the effects of hunting of giant anteaters who are easy targets for sports hunters as reported by locals (pers. comm. 2008) in the Boa Vista region in Brazil.

The main cause for the population decline is declared to be habitat loss in association with other alterations of the anteaters’ environment due to anthropogenic
activities, though there are no actual studies on this topic (Camilo-Alves & Mourão 2006, Mourão & Medri 2007).

The first part of my study on the giant anteater was undertaken in an area that has experienced strong anthropogenic alteration in the last nine years. In the savanna in Northern Brazil timber plantations with trees of the species *Acacia mangium* were planted by the Ouro Verde Florestal Management Ltda., changing the open savanna into a forest habitat. Within the plantations outstandingly high densities of giant anteaters were observed (Kreutz 2007), though there are no studies that quantify the density of the animals in the undisturbed savanna. This is the only reported case in which human activities that are changing the environment seem to have had a positive influence on a population of giant anteaters. In my study I will follow on the results of Kreutz, focussing on behaviour and habitat use of the animals within the plantations and in the adjacent natural landscape.

The second part of my study was conducted in the Dortmund Zoo which is one of the leading facilities in keeping and breeding giant anteaters. Behavioural patterns that were observed in the wild are compared to behaviour recorded in captivity. As the free ranging giant anteaters could not be sexed, this part of my study will provide information about sex specific behaviour.

Finally, I want to combine my results from the field and the zoo and suggest modifications to zoo enclosures that might provide more suitable conditions for the husbandry of captive anteaters.
I INTRODUCTION

Tree plantations cover extensive and ever growing parts of the world’s land surface. The combined global area of timber plantations advanced from 130 million hectares in 1996 to 192 million hectares in 2006 which corresponds to a growth of 48% in ten years (ABRAF 2007, FAO 2007). Such plantations are established to produce wood and fibre in large quantities for timber, paper and fuel wood production (ABRAF 2007; Lindenmayer & Hobbs 2004) to meet the world’s growing demand for wood and taking pressure off the natural forests (FAO 2007). As the area of planted forests increases rapidly and at the same time the losses of natural and semi-natural forests rise, especially in the tropics, there is much debate about the conservation value of these artificial landscapes and the implications of them for biodiversity (Lindenmayer & Hobbs 2004, McNeely & Schroth 2006, Baghwat et al. 2008, Brockerhoff et al. 2008). Several surveys have been conducted to compare biodiversity among natural forests and areas transformed to plantations (Bonham et al. 2002, Armbrecht et al. 2005, Attignon et al. 2005) but only a few were conducted in areas where former non-forest habitats have been converted to forest plantations (Corley et al. 2006). The consensus of those studies is that biodiversity in timber plantations is generally reduced, but that these areas are not in all cases the ‘green deserts’ they are claimed to be and that they can sometimes provide habitat for native plants and animals (Gallina et al. 1996, Zanne 2001, Bonham et al. 2002, Lindenmayer and Hobbs 2004, Brockerhoff et al. 2008). The conservation value of forest plantations varies considerably across the range of management intensities and plantation structure (Brockerhoff et al. 2008). Lindenmayer and Hobbs stated in 2004 in their review about timber plantations in Australia that although many species can not be conserved in plantation dominated landscapes, a large proportion of species can be conserved through (sometimes minor) modifications to forest management. They especially underlined the importance of remnant native vegetation directly adjacent to the plantations, providing habitat heterogeneity and important elements for biodiversity such as riparian areas.
As the need for conserving biodiversity is increasingly recognized, many plantation forest managers are adhering to sustainable management guidelines such as those of the Forest Stewardship Council (Brockerhoff 2008, FSC 2008). Although afforestation can potentially be very detrimental for biodiversity in landscapes where the natural vegetation was not forest but a type of open vegetation such as savanna or shrubland (Cabrera et al. 1998, Corley et al. 2006, Brockerhoff 2008), sustainably managed plantation forests can be a tool for conservation if they are established on agricultural- or grazing land in a landscape that was formerly forested. Timber plantations can alleviate the harvesting-pressure on remnant natural forests and in addition provide supplementary, secondary habitat for species that tolerate a certain level of disturbance. Although planted forest systems can not stand alone as conservation areas, they can function as a buffer to protect remnant native forest edges or increase the connectivity between those (Lindernmayer & Hobbs 2004, Mc Neely & Schroth 2006, Bhagwat et al. 2008, Brockerhoff et al. 2008).

In Brazil for example, it is considered to establish plantations of *Acacia mangium* that shall provide timber on one hand and function on the other hand as corridors between the remnant forest patches of the Atlantic forest (Pellens & Garay 1999). Today there are nearly six million hectares of large scale forest plantations (predominantly consisting of exotic trees such as *Pinus* and *Eucalyptus* species) in Brazil and the extent of these areas is growing rapidly at 13% per year (ABRAF 2007, ITTO 2007). While plantation forest often replaced natural forest from the 1960s to the 1980s, today their establishment occurs increasingly in areas that were earlier deforested for agricultural development (Brockerhoff et al. 2008). It is predicted that by 2011 the per annum increase in the extent of tree plantations will reach one million hectares (EMBRAPA 2008). Due to those large areas devoted to monoculture forest plantations, environmental groups are already pushing for a focus on sustainable management of the plantations for the long-term conservation of wildlife (Barlow et al. 2007). However, although there are some studies that try to evaluate the wildlife value of extensive monocultures in Brazil (Höfer et al. 2001, Barlow et al. 2007), they are still poorly understood and the current knowledge base is insufficient to predict to what extent these habitats can help to conserve tropical forest species in the future (Brockerhoff et al. 2008). Another unpredictable factor is the increasing establishment of wood plantations on natural savanna soils in Brazil. To date there are no studies on the implications of these plantations on the regional biodiversity.
Studies from Patagonia and Venezuela dealing with invertebrates presume a higher fragility of savanna ecosystems to wood plantations when compared to former forest habitats. A study dealing with insect diversity in the acacia plantations of the Ouro Verde Florestal Management Ltda. in the savanna of Northern Brazil showed that the biodiversity was remarkably reduced after the planting procedure, presumably because of the removal of native vegetation. In the first six months after planting, an intensive re-colonization by several species, especially ants, began. After six months or more the insect community was relatively diverse and abundant but remarkable differences to the former faunal composition existed. The succession of the insect fauna seems to be highly correlated with the age of the trees within the plantation. It is assumed, that the high abundance of insects of the order Hymenoptera, especially ants, is one of the factors that leads to the observed high abundances of giant anteaters in the plantations (IBAM 2006, Kreutz 2007).

The aim of my study was to determine social organization, habitat use and diet of giant anteaters within the plantations and the neighbouring landscape, findings that might aid in the effective conservation of these animals. Only very few studies on giant anteaters have dealt with their social organization. In 2005 I conducted a study concentrating on the scratching trees of giant anteaters, very common within the plantations. My results from that study led to the presumption that the scratching trees are part of an unknown, indirect communication system among the animals. I will relate these results to my present study and introduce some new aspects of sociality and indirect communication among giant anteaters. Additionally, the results of my study will provide a better understanding of the basic habitat requirements of giant anteaters, indispensable information for the effective conservation of the animals in the future.

The giant anteater is an animal that normally suffers population decline in areas which have been highly altered by humans. In my study I aim to answer the question of which factors are responsible for the anteaters’ abundance in the plantation forests of northern Brazil. My results will provide some basic implications for sustainable plantation management which is of increasing importance in a tropical country such as Brazil where the landscape is rapidly altering as a consequence of anthropogenic activities.
II MATERIALS AND METHODS

1 Study area

The *Acacia mangium* plantations are situated within a 150 km radius around the city of Boa Vista in the State of Roraima in Northern Brazil (2° 71’ N, 60° 96’ W)(fig. 3). *Acacia mangium* is a fast growing pioneer-tree that is native to Asia. Since 1999 the Ouro Verde Florestal Management Ltda. has been planting this tree over an area of 29,000 ha for timber and cellulose production. Accidentally, the species *Acacia auriculiformis* occurs as well in low numbers in the plantations. Due to its softer wood it can not be used for timber-production, but the two species can not be distinguished as seedlings. Unlike many other species of acacia, *A. mangium* and *A. auriculiformis* show adaptations to ant-associations.

The trees in the plantation are harvested after a minimum of nine years. To increase wood production, a process of thinning is carried out once in every plantation unit. Thinning is a management procedure where dead and un-promising trees as well as all individuals of *A. auriculiformis* are cut down and afterwards left within the plantations.

In February 2008, Ouro Verde Ltda. was awarded with the Forest Stewardship Council (FSC) certificate. The FSC is an international non-profit organization which promotes the responsible management of the world’s forests by setting standards for and providing independent certification and labelling of, sustainably produced forest products (www.fsc.org, 2008).

The natural landscape surrounding the plantation consists of savanna, known locally as ‘lavrado’, which is part of the “Savannas of Guyana” eco region of the Amazonian biome (Ferreira 2001, Capobianco *et al.* 2001). The vegetation is open and dominated by the herbaceous stratum (herbs and grasses) (Barbosa 2007). Interactions between climate, soil type and the fluctuating dynamics of the water table have formed a mosaic of habitats. Small forest patches are spread out over the lavrado which is also characterised by the presence of marshy lakes and ‘buritizais’ - small brooks accompanied by stands of buriti-palms (*Mauritia flexuosa* L.). These aquatic ecosystems play an important function as drainage networks in the wet season but are often completely waterless in the dry season.
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The climate of the savannas of Roraima is Aw (tropical and humid without a cold season) under the Köppen classification (Nimer 1972; Barbosa 1997) with mean temperatures varying from 26° to 30°C throughout the year. The annual average precipitation is 1612 ± 400 mm and the monthly average relative humidity ranges from 66 - 82% (for the period 1910 – 2003; Barbosa 2007). The climate shows a distinct seasonality with a dry summer and a rainy winter. The wettest months are between May and August (with circa 70% of the annual precipitation) and the driest months are between December and March (circa 10% of the annual precipitation). There is limited knowledge of the faunal biodiversity of the savannas of Roraima with invertebrates and mammals being the least-studied groups. There is no comprehensive list of the mammal species that occur in these savannas. However, data collections mainly conducted in the forest patches have counted a total of 102 mammal species including 48 bats (Barbosa 2007). Amongst these are a number of vulnerable species or species in danger of extinction including *Tapirus terrestris* (tapir), *Pteronura brasiliensis* (giant river otter), *Mazama americana* (brocket deer) and the giant anteater (IUCN 2007).

Fig. 3: Location map showing the *Acacia mangium* plantations belonging to the Ouro Verde Florestal Management Ltda in the vicinity of Boa Vista, Roraima Province, Brazil.
2 Study period
The current study was initiated in November 2007 and lasted until the end of February 2008 (28 November 2007 – 22 February 2008) during the North Brazilian summer months.

3 Home range, habitat use and behaviour
In this project the size of home ranges and the spatial organization of giant anteaters within and around the plantations were investigated. Habitat preferences were determined and behaviour patterns (see 3.2.3) were related to the different habitats.

3.1 Study area
The study area was located in the south-western part of the plantation. The whole plantation is subdivided into ‘talhões’ - small management units with a size of 10 to 40 ha. Each talhão is surrounded by a five meter wide road. My study site comprised eight talhões with an area of 91 ha. The complete size when including the surrounding savanna adds up to 144 ha. The trees in the study area were planted in 2001 (fig. 4).

Fig. 4: Study area for the determination of home range organization and habitat use of giant anteaters in plantations of A. mangium in northern Brazil. A detailed map-description can be found on the next page.
Several factors influenced my choice of this part of the plantation as the study site. These included:

- The vegetation is very open, with few shrubs and only little understory, which facilitated locating the animals.
- No thinning of this part of the plantation, which could possibly have influenced the distribution of scratching trees, had occurred.
- Besides the plantation-units, this study site included most types of landscape elements characteristic of the savanna: buritizais as well as a lake and parts of open grassland (fig. 5).

Within my study area I distinguished between a core area, consisting of five talhões in the north-west and a secondary area consisting of three talhões in the south east (fig. 6). This distinction was necessary because of two issues that arose during research in secondary area:

- The road there was not completely passable. Therefore it was not possible to drive around all of the talhões.
• The growth of the trees was very poor in this area. Hence the vegetation was a mix of savanna and plantation which could have posed a problem during the analysis of habitat preferences (fig. 6).

![Figure 6](image.png)

Fig. 6: Study site within *A. mangium* plantations in northern Brazil with the core area (red outlined talhões and savanna which surrounds it) and secondary area (green talhoes without red outlines and surrounding savanna). Talhoes in the secondary area were characterized by very poor growth of acacia trees and a resultant mixture of plantation and savanna habitats (photograph).

### 3.2 Data collection

#### 3.2.1 Locating giant anteaters

Giant anteaters within the study area were located by actively combing the study site by car. Two observers drove slowly (approximately 15 - 20 km/h) along the roads which surrounded the talhões one observing the left, the other observing the right side. Maximum distance of vision within the talhões was ± 40 m and in the surrounding savanna ± 100 m. For each observation day time spent searching and the number and duration of anteater-sightings were noted. Additionally the dominating weather-condition for mornings and afternoons were recorded. It was distinguished between sunny (no or only few clouds, direct sun light), cloudy (sky completely covered with clouds), rainy (clouds and rain) and unsettled (sky not completely covered with clouds, sometimes sunny, sometimes not).
Whenever an animal was located I approached it on foot attempting to keep downwind. The animals appeared to be generally unaware of my approach probably because of their poor eyesight and hearing (McAdam & Way 1967). Hence, observations within a distance of 10 meters or less were possible.

For every anteater located the state of activity (active/inactive), weather conditions, time of day and the habitat type where it was found were noted. The geographic coordinates of each animal were recorded using a global positioning system (GPS; Garmin 76CSx) before continuing further data collection.

3.2.2. **Distinguishing between individuals**

For recording individual movement patterns, home ranges and behaviour, the identification of individual animals within the study area was indispensable. Therefore a database was created including photographs and descriptions of every giant anteater located in the study area. Photographs were taken on a digital camera (Sony α100). Individual giant anteaters could easily be distinguished by their characteristic attributes (fig. 7) and were given consecutive identification numbers. Individually identifiable attributes included black marks on the forelegs or the shape and extent of the stripe on the animal’s shoulder (fig. 7). To identify animals that were found asleep, I woke them up by making noise until they stood up and a photograph could be taken. Afterwards the animals were left alone and in most cases they lay down to sleep again.

![Fig. 7: Examples of characteristics which allowed for the recognition of individual giant anteaters within the study area. Recognizable features were for example the shape and the intensity of the white stripe above the black band on the shoulder of the animal, especially its distance to the ear. Also black shadows or dots on the forelegs facilitated discrimination.](image-url)
3.2.3. **Data collection of movement and behaviour of giant anteaters**

Data were collected during daylight hours between 6:00 and 18:00. I observed giant anteaters on an opportunistic basis as often as possible. For analyzing movement patterns, home range organization and habitat use, the anteaters were first detected through car based observation and then individually identified. Afterwards I tracked them and recorded both movements and behaviour via the handheld GPS-device as will be explained in the following.

Data collection was conducted through “Ad Libitum Sampling” (Altmann, 1974), following the animal as close and as long as possible without disturbing it. GPS positions (subsequently called “waypoints”) were recorded:

1. at 5-min intervals
2. when anteaters entered different habitat
3. when behaviour not connected to foraging and normal movement were displayed (see “recording behaviour”, page 18)

The anteaters reacted to the noise of footsteps on dry leaf litter making it more difficult to follow them in the plantations than on roads or in open areas where observation distances of 5m or less were possible. Therefore a majority of data collections where carried out observing the animals in the plantations from the plantation border. When following an anteater I tried to approach it as near as possible. When the animal interrupted foraging and sniffed in the air I stopped immediately and did not try to diminish the distance anymore. With sniffing in the air the animals seem to check their environment when they heard a sound or smelled anything. If they can not ascertain any implications for a disturbance when sniffing, they subsequently go on with foraging as before.

Because I always had to hold a certain distance, I never recorded the precise location of the animal. This was a problem when later analysing habitat use and spatial organisation. It was solved as follows:

During observations of an anteater from the plantation border or within the plantation I was always positioned on a straight, orthogonal line between the anteater and the nearest road. When recording a waypoint, the distance to the anteater was estimated and recorded in five meter steps (5 m, 10 m, 15 m and so on) together with the waypoint name (fig. 8). Within the plantations accurate estimation on a five-meter-scale was possible, because trees were planted at a constant distance from each.
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Afterwards the GPS positions were mapped with ArcGIS 9.2 (ESRI Environmental Systems Research Institute, Redlands- California, USA 2006) and corrected with the help of the recorded distance information. A digital map of the whole plantation area with the surrounding landscape was provided by the Ouro Verde Ltda.

Recording behaviour: Because Kreutz already determined foraging behaviour of giant anteaters within the plantations, I concentrated on other aspects of the animals’ behaviour. Therefore behaviour was not recorded if it was connected to foraging behaviour or normal movement manners.

Not recorded, but frequently displayed behaviours were:

- Walking straight on with the head held up (fig. 9)
- Standing without any other obvious activity
- Searching for food with the nose on the ground (fig. 10)
- Feeding at one place with observable movement of the tongue muscles (fig. 11)
- Sniffing in the air with the nose held up high (fig. 12)
Fig. 9: Giant anteater walking with its nose held high.

Fig. 10: Giant anteater searching for food with the nose on the ground.

Fig. 11: Giant anteater feeding in the ground.

Fig. 12: Giant anteater sniffing in the air.
The following behaviours were recorded:

- Running: displayed when the anteater noticed my presence or because of bee attacks
- Tree scratching: the anteater stood up on a tree or climbed it. This was always connected with scratching on the bark
- Tree sniffing: defined as a behaviour in which the animal stops at a tree for more than five seconds and obviously sniffs at the bark
- Defecation
- Interactions with water which include drinking and bathing

Behavioural categories were noted with the use of abbreviations (R = Running, Sct = Scratch tree, St = Sniff tree, Df = Defecation, Dr = Drinking, Ba = bathing) and recorded with the waypoint name on the GPS. Additionally the positions of all scratched trees were recorded and photographs were taken.

**Recording habitat use:** Six different habitat types were distinguished within the study area (fig. 13):

- Plantation: stands of acacia trees organized in management units of 10 – 40 ha (talhões, fig. 13, photo 1) and planted in regular rows. Characterised by a poor under-storey (fig. 13, photo 2).
- Savanna: open grass savanna, without any bushes and few trees (fig. 13, photo 3).
- Lake: lake with a size of 0.6 ha and open riparian vegetation (fig. 13, photo 4).
- Buritizai: small brook with a surrounding riparian vegetation of buriti-palms and reed (fig. 13, photos 5a and 5b).
- Channel: artificial drainage channels, without bordering vegetation which fell dry in the middle of January (fig. 13, photo 6).

Every habitat type was named with an abbreviation (Th = thalão, Sv = savanna, Lk = lake with riparian area, Bu = buritizai with riparian area and Ch = channel). As the transition between different habitats was relatively distinct, while tracking I could record the correct time and location when the animal entered a new habitat type.

Occasionally, when the animal lingered in the buritizais, no observation could be undertaken due to the dense vegetation. When it was possible to establish, through sounds made, that the animal still remained in that habitat type, the time the animal spent there was recorded, but no positions were collected.
Fig. 13: Photographs of habitat types in the study area. The numbers in the map above mark their position. Photo 1: aerial photograph of the plantation with the subdivision in talhãos. Photo 2: giant anteater in a talhão of the study site with poor understorey. Photo 3: road and stripe of savanna between plantations and buritizai. Photo 4: lake with poor riparian vegetation. Photo 5a: buritizai with shallow water and Buriti-palms. Photo 5b: riparian area at the buritizai with palm-trees and a reed zone. Photo 6: drainage channel without riparian vegetation.
Summarized the recorded waypoint name contained information about my distance to the anteater at the moment I recorded the waypoint as well as abbreviations representing observed behaviour and habitat types. Additionally time and date were recorded automatically with every position by the GPS-device.

The observation of single anteaters was terminated when the anteater fled as a reaction to my presence or when the location of the animal could no longer be determined. After terminating the data collection a report of the exact displayed behaviour was written.

3.2.4. **Positions of scratching trees and scat**

Scratching trees could be easily identified by the very conspicuous scratch marks in the tree bark produced by the strong fore claws of the anteaters (fig. 14). Within the core area of my study site I walked with two assistants along the rows of trees in the plantation and recorded all positions of scratching trees with a GPS. I also recorded the positions of scat in every third plantation row in the core area during this data collection. Faeces of giant anteaters are easy to locate due to their nearly black colour and a diameter of 15 to 20 cm (fig. 15).

![Fig. 14: Trees with scratching marks, produced by giant anteaters in Northern Brazil.](image)

![Fig. 15: Faeces of giant anteaters.](image)
3.3 Data analysis

3.3.1 Analysis of home range size and spatial organization

In this study the term ‘home range’ refers to the area used by an animal (Burt 1943). I used the software program ArcGIS 9.2 with its software extensions and the external software extension Hawth’s Tools version 3.27 (Beyer 2004) to estimate giant anteater home ranges and conduct further analysis. I used all fixes to determine home range size using the 100% minimum convex polygon (MCP; Mohr 1947). In the MCP-method the outermost recorded locations for a given animal define the limit of its home range. This home range method allows comparisons with previous studies focusing on giant anteater ranging patterns and is considered to be relatively robust, repeatable, non-parametric (Kenward & Hodder 1996; Odum & Kuenzler 1955). Home ranges were also calculated using only locations that are considered to be biologically independent (independent MCPs).

Determining the “Time to independence”: Because the continuous waypoints collected in a single five minute waypoint tracking event are temporally auto-correlated, using those points for home range estimation may result in an underestimation of home range sizes (Swihart & Slade 1985). Fixes are considered as independent, when the time between them is long enough to allow the animal to transverse its home range completely (Hundertmark 1998; White & Garrot 1990).

As the basic home range size for the calculation of the time period the animal needs for the transition, I used the 100% MCP-size generated from all five minutes waypoints of each animal. The maximum diameter that could be measured in a MCP represents the longest distance the anteater had to cover to traverse its home range. As the maximum speed an anteater is capable to walk, I used the maximum speed observed for a normal walking (not running) giant anteater during my observations.

With those data I could determine the minimum period of time an anteater needs to cover the maximum diameter of its home range. Waypoints recorded longer than this time interval were considered as independent locations.

In all further data analyses the term “five-minute waypoints” will be used for all points collected during an observation and “independent waypoints” for points that comply to the requirements of independence.

To determine the area of overlap in the home ranges of giant anteaters, I superimposed the independent MCPs of the individual animals and calculated the
intersection areas for each pair of giant anteaters. I also calculated MCP area-observation curves after Odum & Kuenzler (1955). Here, I took into account the area that accumulated per day the anteater was observed.

**Calculating hypothetical home range sizes:** sizes of home ranges tend to be correlated with the number of relocations and normally increase with sample size. Different authors estimated that 75 percent of the home range size is described when 40 relocations are obtained (Hundertmark 1998). Because many studies (including this one) work with smaller numbers of recorded locations, underestimation is a common problem in home range analyses. In this study I attempt a mathematical approach as a solution to this issue. This method facilitates the calculation of hypothetical MCP sizes that compensate the underestimated area:

A basic problem was that the anteaters were not located on every observation day. In addition I relocated certain animals more frequently than others. On the days I did not locate an individual anteater there were two possibilities as to its location:
1. The animal was in the study site but in those areas that could not be inspected by car (e.g. the interior of the plantation).
2. The animal was outside of the study area and could therefore not be detected by car observation. These days led to underestimation of MCP size.

In the following I will introduce terms, which enable the calculation of the number of days an anteater was assumed to be outside its determined MCP:

\( D_{GA} \) (days with giant anteater) describes the number of days the anteater could be located during my study period. \( A_v \) (visible area) describes the size of the area in the anteater’s MCP that could be inspected during the car observations (fig. 16).

Consequently the relative visibility of the anteater during my study period can be expressed by the term \( D_{GA} / A_v \).

Fig. 16: The violet polygon is an example for a MCP of a giant anteater in my study area in plantations in northern Brazil. The green area \( A_v \) (visible area) is the part of the study site which was visible during performed car-observations while the white area \( A_n \) was not visible by car.
The number of days ($D_n$) the anteater is assumed to be in the area of its home range that could not be inspected during the car observations ($A_n$\textsuperscript{1}, fig. 16) was calculated using:

$$D_n = \frac{D_{GA}}{A_v} \times A_n$$

The number of days on which the anteater was presumably outside of the estimated home range ($D_o$) are now calculated using the days I could locate the anteater in my study area ($D_{GA}$) and the days the anteater was presumably in its MCP but in an area where he could not be detected ($D_n$) subtracted from the complete number of observation days I conducted during my study period ($D_C$):

$$D_o = D_C - D_n - D_{GA}$$

To finally approximate the area missing in my estimated MCP I calculated the average area the MCP accumulates on a day the anteaters can be observed (see “area observation curves”, page 22). This value, multiplied with the number of days the anteater was assumed to be outside my estimated MCP ($D_o$), results in the area by which the MCP is approximately underestimated.

One problem connected to this approach could not be solved in this study: The basic assumption of the function is that the abidance-probability is uniform in the area that is visible ($A_v$) and in the area that is not visible ($A_n$) by car in the MCP. This can not be proved. Behaviour by the animals contrary to this assumption may lead to negative, unusable values being calculated for the underestimated area.

**Kernel-Density-Analysis:** the fixed-kernel-density-estimation (FK) is a method for the estimation of home range size and to determine the utilization distribution density of animals within their home range (Worton 1989). I applied the FK to the independent fixes of the animals. The analysis was set at the 95% isopleths to estimate home range size and at 25% fixed-kernel isopleths to calculate areas of concentrated use (core areas), using probability density functions. The fixed-kernel-isopleths are contours, that contain X\% of the probability density distribution volume. The FK was conducted for every individual giant anteater for which at least 20 locations were obtained. Additionally the percentage of overlap between the core areas was

\textsuperscript{1} $A_n$: Area which was lying beyond of the area that could be observed form the car, e.g. the centre of the plantation.
determined by superimposing the core areas of the individual animals and calculating the size of the intersection areas for each pair of giant anteaters.

To determine the utilization distribution density of all anteaters within my study area, a FK was additionally conducted using the independent fixes of all animals together.

**Analysis of individual flight distances:** during data collection I had to hold a certain distance to the animals for not scaring them up, those distances where recorded with each waypoint (page 16) and represent the individual flight distances. For the comparison of the mean individual flight distances of all the animals, I only used the distances detected in the plantation to exclude habitat specific variations. Differences between the animals were determined by a one-way ANOVA test. A Tukey HSD post-hoc-test was conducted using the results of the ANOVA to facilitate the analysis of differences in flight distance between the animals.

**Analysing travel rates of giant anteaters:** the five-minute-waypoints enabled calculation of the actual distances travelled by the animal and straight line movement in defined time intervals (fig. 17).

- **Rate of travel (km/h):** The travel rate represents the actual distance covered by the anteater during one hour. The five-minute waypoints were used for its calculation. For each giant anteater the average rate of travel was determined. In addition I calculated travel rates displayed by giant anteaters within the different habitat types. To do so, a new five-minute-waypoint-track was begun and counted as a single sample unit every time when the anteater changed the habitat type.

- **Straight line (km/h):** Here, I only included the distance between the first and the last positions of a direct observation and determined the average per hour for each giant anteater.

- **Straight Line (km/24h):** For the analysis of the average distance the anteaters covered in 24 hours, all pairs of relocations of individual giant anteaters that could be recorded in an interval of 24 h ± 5 h were included.
3.3.2. Analysis of habitat use

To determine possible habitat preferences, I calculated a selection index (SI) that was derived from the quotient of proportional time anteaters spent in each habitat and habitat availability in its home range (Fagerstone & Williams 1982). With a SI = 1 the individual has used the habitat in proportion to its availability. SI > 1 indicates selection of the given habitat type while a SI < 1 indicates avoidance. Habitat availability was calculated by the proportion of the habitat features in the MCPs. As the use of only the statistically independent points (3.3.1) would have resulted in the loss of valuable behavioural data (Minta 1993; Rooney, Wolfe & Hayden 1998), the 100% MCPs were used for this analysis.

Statistical data analysis was conducted with R (v. 2.7.0, 2008). Travel rates and the corresponding SI of each anteater in each habitat were correlated using a Spearman’s rank correlation. To determine if the anteaters displayed a different travel rate (km/h) in the disparate habitat types, a GLM (generalized linear model) was conducted. It facilitates to determine whether the reaction of the individual anteaters to the different habitat types was the same.
3.3.3. Activity
The diurnal activity of giant anteaters was defined as the average number of sightings during every hour of the day (6:00 – 18:00). I did not observe the study area at every time of day at exactly the same frequency. To represent the mean diurnal activity of anteaters I divided the number of sightings per hour with the number of hours I observed the study area at the single hours of day during my study period.

To analyse the effects of ambient temperature on activity, a Spearman’s rank correlation was conducted with the mean temperature for every hour and the mean number of sightings at this hour of the day. The hourly temperatures were averaged by the lowest and the highest temperature of day.

A Kruskal-Wallace-Test was made to compare the number of sightings per hour at different weather conditions (sunny, cloudy, rainy and unsettled).

3.3.4. Behaviour
The utilization of riparian zones: Individual differences in the frequency the anteaters visited the riparian areas were determined by means of a Pearson’s $X^2$ test.

Defecating behaviour: Scat distribution was analysed by means of the nearest neighbour index (NNI). It was calculated with the “Average Nearest Neighbour” function by the spatial analyst software extension for ArcGIS 9.2. The nearest neighbour index is expressed as the ratio of the observed distance divided by the expected distance. The expected distance is the average distance between neighbours in a hypothetical random distribution. If the index is less than 1, the pattern exhibits clustering; if the index is greater than 1, the trend is toward dispersion or competition.

Because in many cases more than one scat was found at one spot, a Spearman rank correlation was conducted to determine whether there is a connection between the number of scats per spot and the number of MCP overlapping at this location.

It was further established whether the scat density rises proportionally to the number of anteaters having their home range in the area. I used the determined areas of home range overlap and calculated the scat density for areas with only one home range and for areas were two, three or four MCPs were overlapping. Subsequently I calculated expectation values for a proportional increase. Therefore I used the value that was measured for areas with only one anteater and multiplied it for areas with more than one anteater with the number of animals within. The expectation values were subsequently compared with the measured values.
Scratching behaviour: The distribution of scratching trees was analysed by means of the nearest neighbour index (NNI) as was done for the scat distribution. The density distribution was visualised with a fixed-kernel-density-estimation. Core areas within the 50% isopleth were created using the probability density function. The density of trees in the 50% core areas was compared to the density in the area in-between the percent volume contour at the 95% isopleth and the 50% isopleth. To establish whether the anteater density had an influence on the distribution of scratching trees, the extent to which the 50% core area of the kernel density estimation conducted for the scratching trees overlapped that estimated for all anteaters in the study area was determined.

It was further established whether the scratching tree density rises in proportion to the number of anteaters having their home range in the area. As already done with the scat density, the number of scratching trees per hectare measured for areas with one, two, three or four animals was compared to expectation values\(^2\) that represent a proportional rise with the number of home ranges that are overlapping each other.

4 Diet composition of giant anteaters in acacia plantations

Kreutz could show in his diploma thesis in 2007, that the plantations of *A. mangium* provide an extremely attractive habitat for giant anteaters with high densities of the animals. It is assumed, that nutrition is one of the crucial factors leading to this habitat preference (Kreutz 2007, IBAM 2006). Only a few studies have investigated the diet of giant anteaters in the wild (Montgomery & Lubin 1977, Montgomery 1985, Redford 1985, Shaw 1985). This study shall provide the first details concerning the diet of giant anteaters within plantations.

4.1 Data collection

Samples were collected food items (ants and termites) that could be found at feeding sites of giant anteaters in the five talhões of the core area within the study area. Samples of were collected. Feeding sites were holes created by foraging giant anteaters digging with their fore claws for ants or termites. They have a characteristic shape that originates from the anteaters snout as is pressed into the hole (fig. 18). Before data collection commenced, random sample points within the study area were

Part I Materials and Methods

generated using “Hawth's Analysis Tools” for ArcGIS (v. 3.27, 2007). A total of 42 randomly positioned points were set (fig. 19). The points could be transcribed onto the handheld GPS and navigated to in the field.

After locating a point, the nearest feeding site was searched for and only this one sampled. When a feeding site was found, I expanded the hole with a small shovel to look for nests of ants or termites. When a nest was opened I waited for ants or termites to emerge and collected samples which were preserved in 99.5% ethanol. When no nest could be located in the feeding spot or no animals came out of the opened nest for more than five minutes, I moved on to the next feeding sign that could be found and sampled this.

4.2 Data analysis

Ant- and termite species were identified by the Museu de Zoologia-Universidade de São Paulo (MZUSP) under the supervision of Carlos Roberto F. Brandão.
5 The Influence of plantation thinning on the distribution of scratching trees

In my study in 2005 I established that anteaters in the plantations of the Ouro Verde Florestal Management Ltda. prefer scratching trees of a certain shape. During the tree thinning process in the plantations trees of that shape are removed. This leads to the assumption that thinning has a marked influence on scratching tree distribution.

In this study I compared distribution, shape and the number of scratching trees before and after thinning. Additionally, distribution, shape and the number of scratching trees immediately after thinning was compared to data collected after six weeks.

5.1 Study area
The study took place in two talhões in the south-eastern plantation area near the city of Boa Vista that were thinned in the time of my study (fig. 20).

![Study area map](image)

Fig. 20: Study area where the influence of thinning on the distribution of scratching trees of giant anteaters was determined. The two green polygons in the right picture mark the two talhões in which the study took place (numbers display the talhão code). Location: Plantations of A. mangium in the Boa Vista plain in Northern Brazil.

5.2 Study period
The first data were collected on the 9th of January, directly before the thinning procedure in the two talhões was carried out. The second survey took place one day after thinning. Additionally a data collection was conducted after six weeks on the 26th of February.
5.3 Data collection

Positions of all scratching trees within the study site were recorded with a handheld GPS device. Trees were classified within three categories; classification was conducted via visual estimation (fig. 21):

- Straight: 0° - 5° from plumb line
- Inclined: 5° - 15° from plumb line
- Very inclined: >15° from plumb line

Fig. 21: Scratching trees of giant anteaters within acacia plantations in Northern Brazil with a straight (1), inclined (2) and very inclined (3) trunk

5.4 Data analysis

Pearson’s $X^2$ test was conducted to compare the inclination from plumb line of scratching trees before and after the thinning-procedure. To visualize the density distribution of scratching trees before and after thinning I generated fixed-kernel-density-estimations with the scratching tree positions. Core areas at the 50% isopleth were created for scratching tree positions before thinning, directly after thinning and after six weeks using the probability density function. Their overlap was determined by superimposing the core areas and calculating their intersection.
III RESULTS

1 Home range, habitat use and behaviour

Anteaters were located 80 times in 166 hours of observation drives. The majority of anteater sightings, 74, occurred in the plantation and 6 in the savanna. Eight giant anteaters could be individually differentiated at the study site during my observation period (fig. 22, photograph 1-8). Due to the lack of sexual dimorphism of giant anteaters the animals could not be sexed. The number of sightings varied for each giant anteater. Six anteaters were seen repeatedly on different days (GA1 – GA6) and the time between relocations ranged from 1 to 43 days with a mean of 16 ± 24 days. The other two animals (GA7 & GA8) were only seen once (tab. 1). GA7 was found resting in the study area on one of the first observation days (6 Dec 2007) and was afterwards never seen again. On the very last observation day (19 Feb 2008) GA8 was seen scratching and sniffing intensively at several trees at the study site. These two animals are not included in the following analysis of home range and movement patterns.

Movements and behaviour of anteaters were observed for 36 hours. Duration of single observations ranged from two minutes to one hour and 40 minutes (average: 25 ± 26 minutes). A total of 607 location fixes were recorded for all giant anteaters, with a maximum of 222 waypoints collected for a single anteater (GA1; tab. 1).

The mean flight distance within the plantation between observer and animal was 20 ± 11 m (minimum 15 ± 10 m; maximum 26 ± 13 m) during data collection. The one-way ANOVA showed, that flight distances differed significantly among the animals (F (5, 395) = 13.08; p < 0.001). With the Tukey HSD test it could further be shown, that the flight distance of GA2 and GA3 was significantly lower than that of the other anteaters. Only GA4 showed no significant differences to none of the other anteaters (fig. 23; α = 0.05; MQ = 112.58).
Pic.1: GA1 with a black spot on its forelegs and its white stripe ending long before its ear.

Pic.2: GA2 with white forelegs, and thick stripe reaching to near its ear.

Pic.3: GA3 with a white “butterfly” shape on its foreleg, its thin stripe ending long before the ear.

Pic.4: GA4 with a thick, irregular white stripe, the black stripe remaining open at the back.

Pic.5: GA5 with an distinct white stripe and a big, black spot on the forelegs.

Pic.6: GA6 with black stripe tapering sharply to the back and a faint black shadow on the foreleg.

Pic.7: GA7: white forelegs, irregular white stripe and hardly any white fur under the black stripe.

Pic.8: GA8 with dark fur, an extremely faint white stripe and grey forelegs.

Fig. 22: The eight giant anteaters identified in my study area in Northern Brazil with examples of characteristics that helped to distinguish between the individuals.
Tab. 1: Observation data of eight giant anteaters, occurring in my study area in plantations of *A. mangium* in Northern Brazil (GA = Giant anteater).

<table>
<thead>
<tr>
<th>ID</th>
<th>Day of 1st sighting</th>
<th>Obs. Duration</th>
<th>No. of Sighting-days (DGA)</th>
<th>% sighting-days of obs. days (Dc=31)</th>
<th>Total fixes</th>
<th>Mean distance to GA in plantation mean ± SD (n)</th>
</tr>
</thead>
<tbody>
<tr>
<td>GA1</td>
<td>28 Nov 2007</td>
<td>13:42</td>
<td>16</td>
<td>52</td>
<td>222</td>
<td>23 ± 10 (173)</td>
</tr>
<tr>
<td>GA2</td>
<td>29 Nov 2007</td>
<td>6:29</td>
<td>8</td>
<td>26</td>
<td>73</td>
<td>15 ± 10 (40)</td>
</tr>
<tr>
<td>GA3</td>
<td>28 Nov 2007</td>
<td>11:33</td>
<td>18</td>
<td>58</td>
<td>221</td>
<td>16 ± 11 (126)</td>
</tr>
<tr>
<td>GA4</td>
<td>06 Dec 2007</td>
<td>2:09</td>
<td>11</td>
<td>35</td>
<td>40</td>
<td>19 ± 9 (9)</td>
</tr>
<tr>
<td>GA5</td>
<td>13 Dec 2007</td>
<td>2:43</td>
<td>4</td>
<td>13</td>
<td>36</td>
<td>26 ± 13 (27)</td>
</tr>
<tr>
<td>GA6</td>
<td>26 Dec 2007</td>
<td>2:00</td>
<td>6</td>
<td>19</td>
<td>26</td>
<td>25 ± 8 (26)</td>
</tr>
<tr>
<td>GA7</td>
<td>06 Dec 2007</td>
<td>0:05</td>
<td>1</td>
<td>3</td>
<td>1</td>
<td>15 ± 0 (1)</td>
</tr>
<tr>
<td>GA8</td>
<td>19 Feb 2008</td>
<td>0:57</td>
<td>1</td>
<td>3</td>
<td>26</td>
<td>22 ± 9 (22)</td>
</tr>
</tbody>
</table>

1.1 Home range size and spatial organisation

I generated home range estimates using four different methods (tab. 2):

1. **100% MCPs generated with all collected fixes for each giant anteater:** 100% MCPs ranged from 4 to 128 ha with a mean size of 49 ha (n = 6, SE = 0.42).

2. **Independent MCPs generated through independent pairs of relocations:** A pair of relocations of giant anteaters was considered as independent when a time span of one hour or longer lay between the two points. This was calculated as follows: The

![Figure 23: Flight distances of six giant anteaters (GA) in Brazil. The flight distance of GA2 and GA3 was significantly lower than that of GA1, GA5 and GA6. GA4 showed so significant difference to none of the animals.](image-url)
mean maximum diameter for all 100% MCP-home ranges was $1.23 \pm 0.39$ km. The maximum observed travel rate of an (not running) anteater was $1.28$ km/h\(^3\). With this travel rate the animal is theoretically capable of traversing a distance of $1.23$ km and thus its home range in 57 minutes. This was rounded up to one hour.

MCP home ranges generated with independent points ranged from 3 to 124 ha, resulting in a mean home range size of $44 \pm 41$ ha (tab. 2). Although the MCP size was not correlated with the number of sightings (Spearman’s $R = 0.657$, $p = 0.175$), most of the generated MCPs were assumed to be underestimates as a result of the low number of independent waypoints. Only two of the area-observation curves reached the asymptote (fig. 24 - fig. 29): the curve of the anteater with the most sighting-days (GA3; n=18) and the anteater with the smallest MCP home-range (GA6; fig. 29). He latter animal was seen on six days but only in a small part of the study site.

3. Hypothetical MCPs, based on independent MCPs: these were calculated by including the number of days an anteater was assumed to be outside of its home range in an attempt to compensate for underestimation. This calculation revealed a mean MCP size of $135 \pm 48$ ha (tab.2). Hypothetical home ranges and following analyses could only be calculated for the animals GA1 to GA5. Because the independent MCP of GA6 was completely positioned in the area that was not observable by car ($A_n$) the function produced in this case negative values and therefore no hypothetical home range could be generated.

With the exception of GA5 who had a distinctively larger hypothetical home range than the other anteaters, the variation between the calculated MCP-sizes was significantly lower than that between the independent MCPs generated through data-collection. This could be shown by calculating the coefficient of variation, which is the product of the standard deviation and the mean value. Considering all home ranges the variation coefficient was higher for the MCPs generated through data collection ($vc = 0.74$) than for the hypothetical ones ($vc = 0.56$). If GA5 is not considered in the calculation of the coefficient of variation it can be shown, that the variance of the other hypothetical MCPs is extremely low ($vc = 0.11$) and that of the independent MCPs remarkably higher ($vc = 0.74$) (tab. 2).

---

\(^3\) maximum travel-rate of an anteater that was not running. A running anteater could be observed at $2.5$ km/h
By summarizing it can be concluded, that the hypothetical home ranges of GA1 to GA4 have nearly the same size, while the independent MCPs show considerably different sizes. The larger home range of GA5 may have resulted from the fact that this anteater was seen running in two of four sightings due to bee attacks. Therefore it covered more space in a shorter time than the other anteaters, resulting in a higher rate of MCP accumulation. During the calculation of the hypothetical home range, the accumulation rate was multiplied with the days the anteater was assumed to be outside of the estimated home range. Therefore high accumulation rates lead to larger hypothetical home ranges.

4. Adaptive kernel density, generated with independent waypoints, respecting: only two animals (GA1 and GA3) had an adequate quantity of independent points that could be used to produce a fixed kernel density analysis (fig. 31). Fixed kernel range size at the 95% Isopleth level was 76 ha for GA1 and 94 ha for GA3 with a mean size of 85 ha (n = 2, SE = 13). High use areas were defined as areas that contain 25% of the probability density distribution volume of the calculated kernel density. The home range of GA1 showed one high use area with a size of four hectares, containing 38% of all independent fixes of the animal. In the home range of GA3 five high use areas could be detected, all together having a size of eleven hectares containing 48% of all independent fixes of GA3.

Tab. 2: Data for eight giant anteaters observed in the study area in plantations of A. mangium in Roraima, Brazil (GA = Giant anteater). Home range sizes (ha) are based on the three Minimum Convex Polygon methods described in the text. 100% MCP was generated using all fixes, the independent MCP was generated using all independent points and the hypothetical MCP was calculated using a function in an attempt to compensate for the underestimation of the other MCPs. Home ranges were also calculated, based on the 95% adaptive kernel density method.

<table>
<thead>
<tr>
<th>ID</th>
<th>Total fixes</th>
<th>100%MCP (ha)</th>
<th>Indep. fixes</th>
<th>Ind. MCP (ha)</th>
<th>Hyp. MCP (ha)</th>
<th>95% Kernel (ha)</th>
<th>25% core area (ha)</th>
</tr>
</thead>
<tbody>
<tr>
<td>GA1</td>
<td>222</td>
<td>69</td>
<td>32</td>
<td>64</td>
<td>108</td>
<td>76</td>
<td>4</td>
</tr>
<tr>
<td>GA2</td>
<td>73</td>
<td>38</td>
<td>13</td>
<td>26</td>
<td>128</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>GA3</td>
<td>221</td>
<td>123</td>
<td>32</td>
<td>118</td>
<td>121</td>
<td>94</td>
<td>11</td>
</tr>
<tr>
<td>GA4</td>
<td>40</td>
<td>24</td>
<td>15</td>
<td>22</td>
<td>101</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>GA5</td>
<td>36</td>
<td>33</td>
<td>6</td>
<td>33</td>
<td>218</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>GA6</td>
<td>26</td>
<td>4</td>
<td>7</td>
<td>3</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>GA7</td>
<td>1</td>
<td>-</td>
<td>1</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>GA8</td>
<td>26</td>
<td>-</td>
<td>2</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
</tbody>
</table>
Part I Results

Fig. 24: Independent MCP and associated accumulation curve for a giant anteater (GA1). MCP size is 69 ha. Dots represent all fixes of GA1 and are partly positioned outside the MCP that was generated with independent fixes.

Fig. 25: Independent MCP and associated accumulation curve for a giant anteater (GA2). MCP size is 38 ha. Dots represent all fixes of GA2 and are partly positioned outside the MCP that was generated with independent fixes.
Fig. 26: Independent MCP and associated accumulation curve for a giant anteater (GA3). MCP size is 118 ha. Dots represent all fixes of GA3 and are partly positioned outside the MCP that was generated with independent fixes.

Fig. 27: Independent MCP and associated accumulation curve for a giant anteater (GA4). MCP size is 22 ha. Dots represent all fixes of GA4 and are partly positioned outside the MCP that was generated with independent fixes.
Fig. 28: Independent MCP and associated accumulation curve for a giant anteater (GA4). MCP size is 33 ha. Dots represent all fixes of GA4 and are partly positioned outside the MCP that was generated with independent fixes.

Fig. 29: Independent MCP and associated accumulation curve for a giant anteater (GA6). MCP size is 3 ha. Dots represent all fixes of GA6 and are partly positioned outside the MCP that was generated with independent fixes.
Social Organization and Habitat Use of Giant Anteaters

Fig. 30: Independent MCPs for six giant anteaters in and around A. mangium plantations in Roraima, Northern Brazil.

Fig. 31: The home range size and location of two giant anteaters (GA1 and GA3) using the Minimum Convex Polygon Method (100% MCP) = 0.69 (GA1) and 1.23 (GA3) and the Fixed Kernel Method (95%) = 0.76 (GA1) and 0.94 (GA3). Red contours mark the high use areas, containing 25% of the probability density distribution volume.
**Overlap of MCPs:** The home ranges (based on independent MCPs) of giant anteaters overlapped extensively (79 ± 23 %; n=6) (fig. 32) and the extent of overlapping was different for each animal. The lowest percentage was determined for the MCP of GA2 (37%). GA1 shared the biggest part of its home range with other animals with 99.6% of this area being overlaid by the MCPs of other anteaters, (tab. 3). The proportions by which home ranges overlapped others did not correlate with the sizes of the home ranges (N = 6, Spearman’s R= 0.02, p > 0.05).

In the area where GA6 was located, the largest area with four different MCPs overlapping each other could be detected (fig. 33). Considering all home ranges, the main proportion of their expanse was without any overlaps or overlapped by one other MCP (fig. 33).

The home ranges of GA2 and GA4 were overlapped less intensive than the other home ranges as can be seen in figure 33. Over 60% of the home range of GA2 was not overlapped by other home ranges, compared to a maximum of 30% non overlapped area for the other MCPs. The home range of GA4 was overlapped by one other anteater for 74%, but less than 2% of its MCP was overlapped by more other animals. Of the other home ranges more than 20% were overlapped by two or three animals.

Fig. 32: Overlap of home ranges of giant anteaters in Northern Brazil.
The overlap for each pair of sympatric giant anteaters reached from 0 to 95% (tab. 3). GA3, the animal with the largest MCP, overlapped the MCPs of five other anteaters. GA6, the anteater with the smallest MCP overlapped the MCPs of three other animals and GA4 only overlapped on.

Tab. 3: Per cent overlap in home ranges of sympatric giant anteaters in, and next to A. mangium plantations in Roraima, Brazil. Each cell represents the percentage by which the animal in the row overlapped that in the column. Total overlap = per cent of the total area of each giant anteater that is overlapped by the home ranges of other anteaters.

<table>
<thead>
<tr>
<th>ID</th>
<th>Total overlap</th>
<th>GA1</th>
<th>GA2</th>
<th>GA3</th>
<th>GA4</th>
<th>GA5</th>
<th>GA6</th>
</tr>
</thead>
<tbody>
<tr>
<td>GA1</td>
<td>99.6</td>
<td>-</td>
<td>23</td>
<td>52</td>
<td>2</td>
<td>94</td>
<td>80</td>
</tr>
<tr>
<td>GA2</td>
<td>37.8</td>
<td>9</td>
<td>-</td>
<td>11</td>
<td>0</td>
<td>2</td>
<td>0</td>
</tr>
<tr>
<td>GA3</td>
<td>71.5</td>
<td>96</td>
<td>37</td>
<td>-</td>
<td>74</td>
<td>89</td>
<td>96</td>
</tr>
<tr>
<td>GA4</td>
<td>73.0</td>
<td>1</td>
<td>0</td>
<td>16</td>
<td>-</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>GA5</td>
<td>94.7</td>
<td>47</td>
<td>2</td>
<td>24</td>
<td>0</td>
<td>-</td>
<td>68</td>
</tr>
<tr>
<td>GA6</td>
<td>96.7</td>
<td>4</td>
<td>0</td>
<td>2</td>
<td>0</td>
<td>6</td>
<td>-</td>
</tr>
</tbody>
</table>
The home ranges of GA1 and GA3 were overlapping extensively (tab. 3). Because a Fixed Kernel Density Analysis could be conducted for those two individuals, it was possible to visualize the localization of high use areas within the home ranges. High use areas are defined as sites that comprise 25% of the probability density distribution volume determined by the Fixed Kernel Density. It could be shown that even those areas are overlapping each other for 0.14ha which is consistent with a percental overlap of 9% (core area GA1 overlapping core area GA3) and 25% (core area GA3 overlapping core area GA1; fig. 34).

![Fig. 34: Overlay of areas with high utilization of two giant anteaters in plantations of *Acacia mangium* in Northern Brazil. Core areas are defined as areas which contain 25% of the probability density distribution volume.](image)

Even though most of the estimated home ranges extensively overlapped each other, nearly all of my observations were of solitary anteaters, with no other anteater in sight. Only in one single case were two giant anteaters (GA3 & GA4) seen simultaneously. Both were feeding in the plantation near a road within the same talhão and were approximately 15 m from each other. GA4 was observed to suddenly stop, raise his nose, sniff the air and run across the road into the adjacent talhão. GA3 did not appear to take any notice of the other anteater and continued foraging.
In five more cases two different anteaters were sighted within a time span of 45 minutes or less, moving towards each other within a distance of < 500 m. Given that the mean travel rate of a giant anteater was estimated as being 370 m per hour (see section 1.3), this would make it possible for them to cover 250m in 45 minutes. Thus those sighted anteaters could have met each other within this time span if they had retained their direction of travel. This did not happen in any of the five cases because at least one of them changed its direction. None of these anteaters showed any noticeable change in behaviour indicating that they had noticed the approach of a conspecific.

In the remaining 74 sightings, anteaters located in the study area on the same day were found to be more than 500 m apart from each other.

Considering the sightings of giant anteaters at certain times of days, the animals do not seem to follow a definite “time-table of movement” to avoid encountering conspecifics through a spatiotemporal organization. In 76% of all cases an individual anteater was seen on different days but at the same hour of day it was more than 200m away from other sightings at that time (fig. 35).

Fig. 35: Fixes of a giant anteater (GA3) at certain times of day in and around a plantation of *Acacia mangium* in northern Brazil.
1.2 Densities of giant anteaters
The area that could be scanned during car observations in and around the plantation had a size of 93 ha. Over the complete study period I identified eight different anteaters within this area. Of these, six were located on a number of occasions and were thus assumed to have a part of their home range in my study area. Including these anteaters, a density of 6.5 animals per km² was calculated. However, I never located all anteaters in the observation area on the same day. The maximum number of anteater fixes per day was 4, which was only reached twice during my study period. On average I sighted $2.1 \pm 1.0$ anteaters per day in my study area, resulting in a daily density of 2.26 animals per km².

A Fixed Kernel Density that was generated by using the independent fixes of all anteaters in the study area revealed that the individual anteaters share few areas of high use, while other sites remain nearly unused (fig. 36).

![Fig. 36: Fixed Kernel Analysis for the independent points of all giant anteaters in the study area. It can be distinguished between high use areas (50% core areas) that are highly used by different anteaters and areas which are nearly not used by anteaters.](image)
1.3 Movement patterns and home range use
For the analysis of movement patterns, tracks resulting from the five-minute-waypoint tracking were used as sampling units. The five-minute-tracks contain information about the time the animal needs to cover a certain distance in the different habitat types.

*Speed of giant anteaters:* The average speed of giant anteaters was determined by the rate of travel. The rate of travel represents the actual distance the anteater covered during an observation in one hour and was calculated by using the five minute waypoint tracks. Straight line distances show the spatial displacement of the animals over a certain time interval (tab. 4).

The actual distance the anteaters covered in one hour was averagely 0.37 ± 0.35 in 88 sampling units. Comparisons of travel rates showed no significant difference among individuals (Kruskal-Wallis $H$ Test: $H (5; N = 87) = 0.91; p > 0.05$). In only three cases did anteaters move more than one kilometre in one hour. The maximum observed speed was of GA5 running at 2.5 km per hour due to a bee attack. The minimum of 0.02 km per hour was displayed by GA6 during foraging.

Straight line distances were shorter than the actual distances covered in one hour showing that anteaters don’t move in a straight line. For straight line displacement per hour no significant difference between the anteaters could be determined (Kruskal-Wallis $H$ Test: $H (5; N = 84) = 2.7; p > 0.05$). Differences in sample size between travel rate and straight line movement result from occasions in which visual contact with the animal was lost for more than five minutes. In this case the five-minute-waypoint track had to be abandoned and a new track started when contact of vision was established again. This resulted in two samples for the travel rate, but they could be pooled together to a single sample unit for straight line analysis.

The minimum daily displacement was 0.29 km/24h; the maximum was 1.4 km/24h. Daily displacement could only be examined for GA1, GA3 and GA4 because only relocation pairs that were recorded in a time interval of 24 ± 4 hours were used for this analysis. No relocations of other anteaters met this requirement. No significant differences between relocations for individuals could be determined (Kruskal-Wallis $H$ Test: $H (2; N = 16) = 3.1; p > 0.05$).
Tab. 4: A comparison of the mean rate of travel (km/h) and straight line displacement in one hour and in 24 hours by six giant anteaters (GA) during an observation. Sample size refers to the total number of five-minute-waypoint-tracks, or for daily displacement to the number of relocations within 24 ± 4 hours.

<table>
<thead>
<tr>
<th>ID</th>
<th>Rate of travel (km/h) Mean ± SE (n)</th>
<th>Straight line (km/h) Mean ± SE (n)</th>
<th>Straight line (km/24h) Mean ± SE (n)</th>
</tr>
</thead>
<tbody>
<tr>
<td>all</td>
<td>0.37 ± 0.35 (88)</td>
<td>0.28 ± 0.25 (72)</td>
<td>0.56 ± 0.31 (16)</td>
</tr>
<tr>
<td>GA1</td>
<td>0.32 ± 0.25 (25)</td>
<td>0.20 ± 0.17 (26)</td>
<td>0.52 ± 0.28 (7)</td>
</tr>
<tr>
<td>GA2</td>
<td>0.45 ± 0.37 (16)</td>
<td>0.41 ± 0.39 (13)</td>
<td></td>
</tr>
<tr>
<td>GA3</td>
<td>0.34 ± 0.21 (27)</td>
<td>0.31 ± 0.23 (18)</td>
<td>0.65 ± 0.36 (7)</td>
</tr>
<tr>
<td>GA4</td>
<td>0.38 ± 0.27 (6)</td>
<td>0.32 ± 0.24 (6)</td>
<td>0.41 ± 0.2 (2)</td>
</tr>
<tr>
<td>GA5</td>
<td>0.20 ± 0.06 (5)</td>
<td>0.20 ± 0.13 (6)</td>
<td></td>
</tr>
<tr>
<td>GA6</td>
<td>0.28 ± 0.22 (4)</td>
<td>0.31 ± 0.03 (3)</td>
<td></td>
</tr>
</tbody>
</table>

Habitat feature use: Except for GA6 (this animal was only seen within the plantation), all home ranges contained areas of plantation, savanna and riparian areas in different proportions. The plantation made up the predominant part of the home range areas (from 56 to 100%) and this result is assumed to be related to the procedure of car based observation. This over-representation of the plantation was compensated by calculating the selection index which is the product of time spend in a certain habitat and the availability of this habitat. The SI values revealed a clear preference for plantation and water side vegetation and a marked avoidance of the savanna (tab. 5).

Tab. 5: Selection index (SI: Fagerstone & Williams 1982), calculated from the average proportion of time spent in each habitat and the average proportion of availability of each habitat in the home ranges. A SI >1 indicates selection for a habitat type. SI < 1 indicates avoidance and when SI =1 the animal used the habitat in proportion to its availability. Data were recorded in and next to an *A. mangium* plantation in Roraima, Brazil from November 2007 to February 2008.

<table>
<thead>
<tr>
<th>habitat</th>
<th>mean % MCP</th>
<th>mean % time</th>
<th>SI</th>
</tr>
</thead>
<tbody>
<tr>
<td>plantation</td>
<td>61,6</td>
<td>87,2</td>
<td>1,41</td>
</tr>
<tr>
<td>savanna</td>
<td>34,4</td>
<td>4,8</td>
<td>0,14</td>
</tr>
<tr>
<td>riparian area</td>
<td>1,7</td>
<td>4,0</td>
<td>2,35</td>
</tr>
</tbody>
</table>
The travel-rates, calculated by means of the five-minute-waypoint-tracks showed, that the movement speed was highest for the savanna habitat and considerably lower in the plantation and the riparian area. Giant anteaters covered, on average, more than double the distance per hour when moving in the savanna than in the plantation (tab. 6).

GA4 was the only anteater that reacted differently, moving slower in the savanna than in the plantation. This discrepancy could result from the fact that GA4 was located on nine of eleven sighting days in the border area, which is characterized by very poor growth of acacia trees and a resultant mixture of plantation and savanna habitat. This complicates a comparison between the border area with the rest of the study site and therefore GA4 will not be included in the following analysis of habitat preferences.

<table>
<thead>
<tr>
<th>ID</th>
<th>Rate of travel (km/h) mean ± SE (n)</th>
<th>Mean ± SE (n) 1</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>in total plantation savanna water side</td>
<td>savanna water side</td>
</tr>
<tr>
<td>all</td>
<td>0,37 ± 0,35 (85) 0,25 ± 0,13 (61) 0,73 ± 0,23 (20) 0,15 ± 0,08 (4)</td>
<td></td>
</tr>
<tr>
<td>GA1</td>
<td>0,32 ± 0,25 (26) 0,22 ± 0,08 (21) 0,84 ± 0,14 (4) 0,19 ± 0 (1)</td>
<td></td>
</tr>
<tr>
<td>GA2</td>
<td>0,45 ± 0,37 (17) 0,26 ± 0,16 (10) 0,81 ± 0,34 (6) 0,06 ± 0 (1)</td>
<td></td>
</tr>
<tr>
<td>GA3</td>
<td>0,34 ± 0,21 (27) 0,23 ± 0,10 (19) 0,61 ± 0,12 (8) 0,09 ± 0 (1)</td>
<td></td>
</tr>
<tr>
<td>GA4</td>
<td>0,38 ± 0,27 (6) 0,47 ± 0,30 (3) 0,37 ± 0,27 (2)</td>
<td></td>
</tr>
<tr>
<td>GA5</td>
<td>0,20 ± 0,06 (5) 0,19 ± 0,06 (4) 0,24 ± 0 (1)</td>
<td></td>
</tr>
<tr>
<td>GA6</td>
<td>0,28 ± 0,22 (4) 0,28 ± 0,22 (4) 0,24 ± 0 (1)</td>
<td></td>
</tr>
</tbody>
</table>

A GLM was conducted, using the travel rates of individual animals in the separate habitat types. Three analyses were undertaken to determine the reactions of anteaters to different habitat types:

1. It was determined whether significant differences between the travel rates of the five giant anteaters exist without considering habitat type as a factor. It could be shown that individual anteaters did not move at significantly different speeds (F= 0.8581, df= 4, p > 0.05).
2. Data of all the anteaters were pooled together to examine differences between travel rates in the three habitat types. The analysis revealed significantly different reactions of the animals to the habitat (F= 80.24, df= 2, p < 0.001).

3. By means of the GLM, interactions between single animals and habitat type could be determined. No significant differences in the reaction of individual anteaters to the different habitat types could be found (F= 1.8884, df= 4, p > 0.05).

It could be shown that the anteaters moved at different speeds in the different habitats (tab. 6) and that the reactions of the anteaters to different habitat types were all the same with highest speed in the savanna habitat and a lower travel rate in the plantation and the riparian zone.

Comparing travel-rate and the selection index of the anteaters in the different habitat types showed a significant negative correlation (fig. 37). The higher the selection for a habitat feature was, the slower the animals moved within it.

![Graph](image_url)

Fig. 37: Spearman's rank correlation, comparing travel rates of five anteaters in three different habitats types and their selection index for those habitat types. Data collected in Roraima, Northern Brazil. Each of the 11 sample point stands for an individual anteater in a certain habitat. Not every anteater could be observed in every habitat type.
**Direction of movements:** In addition to the values for the travel rate the mean straight line displacement per hour in each of the three habitat types was calculated. Straight line distances per hour showed the same tendencies as travel rates, being highest in the savanna and lowest at the water side.

Straight line displacement and travel rate were compared. By calculating the differences between the two factors the way in which the animals moved could be shown, with stronger meanderings in relation to the straight line leading to a bigger the difference between travel rate and the straight line value (fig. 38 & 39). Discrepancy between travel rate and straight line displacement was distinctly higher within the plantations and the water side than in the savanna.

To summarize, it can be said that giant anteaters move quicker and straighter in the savanna than in the plantations. This was also supported by personal observations: In eleven of 13 cases in which anteaters were observed in the savanna, they continued more or less directly to the next buritizai, never spending more than 15 minutes in the savanna (mean: 8 ± 3 minutes, fig. 39). Only in two cases was GA3 encountered crossing the south-eastern part of the savanna (fig. 39, black frame). He was observed approaching talhãos in the border area and in both cases spent more than 25 minutes in the savanna.

![Graph showing differences between travel rate and straight line displacement](image)
1.4 Activity of giant anteaters

In the following analysis, activity is described by means of sightings of active giant anteaters per hour.

**Diurnal activity rhythm:** The mean daily activity of giant anteaters in and around the plantation was determined for the period of 6:00 to 18:00 over the study period. It reached peaks at seven (8.2 sightings per hour) and nine o'clock in the morning (8.4 sightings per hour). At 13:00 a low point in activity was arrived at with 0.2 sightings per hour, increasing constantly over the afternoon up to 0.5 sightings after 17:00.

Considering the development of temperature over the day (fig. 40), a significant negative correlation between mean temperature and number of sightings per hour of day time could be determined (fig. 41). Anteaters were more active in hours with low temperatures. However, no periods of complete inactivity were observed.
Fig. 40: Activity patterns of giant anteaters in plantations of *A. mangium* and the surrounding landscape in Roarima, Brazil. The black curve shows the mean temperature over the day during the period of data collection. Sightings per hour were calculated using the number of sightings at different times of day and the number of observation hours that were conducted at this time.

![Activity patterns of giant anteaters](image)

Fig. 41: Correlation between temperature and activity of giant anteaters at different times of day.

![Correlation between temperature and activity](image)
Activity and weather conditions: The dominant weather conditions for the mornings and afternoons of each observation day were noted. No significant differences between the number of active anteaters at different weather conditions could be detected (Kruskal-Wallace-Test: H (3, N = 58) = 3.7; p > 0.05). Nevertheless a tendency was found for lower activity during sunny weather (average: 0.26 ± 0.26 sightings / hour) and increased sightings during cloudy weather (average 0.48 ± 0.37 sightings per hour) (fig. 42).

![Activity of giant anteaters during different weather conditions in and around plantations of A. mangium in Roraima, Northern Brazil.]

Sleeping habits: Sleeping giant anteaters were always found lying curled up with the body covered under the bushy tail. No defined “sleeping-times” could be detected but the most sleeping animals were located in the morning hours between 6:00 and 9:00 (fig. 43). Individual anteaters showed no tendencies to sleep always at the same time of day. GA3 for example was located sleeping on five different days, mostly on different daytimes (at 8:11, 11:30, 11:58, 12:45, 16:36). On a single occasion it was observed how it lay down for sleeping at 11:30 directly besides the road. Afterwards it could be located every hour. It was seen sleeping for 6:49 hours, and then the observation had to be terminated because it was getting dark. Altogether fourteen sleeping sites of anteaters were recorded and these showed no particular structure. In seven cases anteaters were already resting when located, in the seven other occasions anteaters lay down to sleep during an observation. When an anteater was disturbed while sleeping, it stood up, walked some metres and lay down again at another place.
Individual anteaters were never observed using the same sleeping site twice (fig. 44). On twelve occasions anteaters were found resting within the plantation and on two occasions they were observed, lying down to sleep outside the plantation under short, bushy palm trees (fig. 44). No anteater was ever seen sleeping in the open savannah or was observed to lie down in this habitat. Due to their very efficient camouflage it was not easy to detect resting anteaters in the plantation. However, locating giant anteaters within savanna or buritizai was nearly impossible due to the dense grass cover. Hence those habitat types were likely under-sampled compared to the plantation.
2 Behaviour

2.1 The utilization of riparian zones by giant anteaters
Riparian zones in my study area included the area immediately around buritizais, channels and lakes. On 13 days (over 31 observation days) in 16 cases the anteaters GA1 to GA5 were directly observed visiting this habitat.

On three other occasions anteaters (GA2 and GA3) were found foraging inside the plantation near a buritizai with wet fur. Because it was not raining I assumed that the animals had just visited a water-source (fig. 45) and these two events were counted as well.

Anteaters could be seen visiting riparian zones throughout the day between 9:00 and 18:00 with peaks in frequency about noon (fig. 46).

Individual anteaters showed significant differences in the frequency with which they visited riparian areas (Pearson’s $X^2 = 15.3; N = 63; p<0.05$ fig. 47). All the sightings of GA6 were within the plantation and never at a water side, while GA2 was found visiting buritizais on most of the days he was observed.
I could not determine any influence of daily weather conditions on the frequency of visits at riparian zones by giant anteaters. Mean daily temperatures of days with and days without anteaters visiting those areas showed nearly no difference (tab. 7). Precipitation showed strong variations during the study period. Of the fifteen days without any anteater visiting water sources five days were rainy with a maximum precipitation of 35mm. Of the sixteen days with an observation of an anteaters visiting a water-source there were eight days with rain and a maximum precipitation of 65 mm (tab. 7), but it was never raining in the moment the anteater visited the riparian zone.

Fig. 46: Number of giant anteaters visiting riparian zones in the surroundings of plantations of *Acacia mangium* in northern Brazil per hour of observation at different daytimes.

Fig. 47: Days with anteaters visiting water sides as a percentage of all days the individuals were observed. Data collected in plantations of *Acacia mangium* in Northern Brazil.
Tab. 7: Average weather conditions on days giant anteaters visited water sources within their home range and on days when anteaters were not observed visiting water sources. Observations were carried out in and around plantations of *Acacia mangium* in Northern Brazil.

<table>
<thead>
<tr>
<th>No. of obs. days</th>
<th>mean temperature (°C)</th>
<th>mean precipitation (mm)</th>
<th>mean wind speed (m/s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>days with water-sighting</td>
<td>13</td>
<td>28.6 ± 0.7</td>
<td>3.3 ± 9.2</td>
</tr>
<tr>
<td>days without water-sighting</td>
<td>18</td>
<td>28.3 ± 1.4</td>
<td>7.7 ± 15.3</td>
</tr>
</tbody>
</table>

Observations of behaviour were complicated when anteaters visited buritizais due to the dense understorey and deep mud at their edge. Nevertheless on six occasions direct observations of giant anteaters in riparian areas were possible. Five different kinds of behaviour were displayed by anteaters at a water side:

1. **Drinking**: in five of the six direct observations anteaters were drinking at the water source. In one case it was observed that an anteater dug next to the brook and drank the water that filled up the hole. In the other observation anteaters drank directly from the water sources. On two occasions GA3 was seen following the drainage channel in the south-eastern part of the study site, drinking while it walked without stopping (fig. 48). During one of these observations it stopped to defecate, drinking in the meantime and continuing to drink next to its faeces.

2. **Bathing**: in one observation GA2 could be watched bathing in the 30 cm deep water of a buritizai from a distance of three meters: After arriving at the brook it first lay down, stretched out in the water and rested for two minutes with the eyes closed. Subsequently it began grooming its fur over the whole body with its fore claw in alternated lying and sitting postures. While grooming it constantly sniffed at the spots it groomed. After finishing it lay down again, resting with eyes closed for several minutes before approaching back to the plantation. The whole procedure lasted twelve minutes (fig. 49 – fig. 50). Bathing could be detected two more times in an indirect way: I lost visual contact when the anteater entered the dense riparian vegetation that surrounds the buritizais, but could locate the animal immediately when it left the buritizai after more than ten minutes, with completely wet fur.
3. **Defecating:** as already mentioned GA3 was seen defecating in the water. On two other occasions piles of faeces could be located within the drainage channels.

4. **Resting in buritizais next to the water:** anteaters were witnessed in two cases lying down under short, bushy palm trees, once next to the water of a buritizai and once next to the lake. Sightings of sleeping anteaters at water sites are assumed to have been under estimated as locating them inside the buritizais was almost impossible due to the dense understorey and the perfect camouflage of the animals.

5. **Traversing water sources:** in one case the water of a drainage channel in the southern part of the study area was crossed by GA2, without drinking or bathing to reach the talhãos on the opposite bank. GA2 was witnessed one and a half hours before, having a bath and drinking at the buritizai in the north.

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*Fig. 48: Giant anteater walking in a drainage channel next to plantations of Acacia mangium. The animal is drinking and walking at the same time.*
Part I  Results

Fig. 49: Giant anteater grooming its fur with the fore claw while having a bath. The photo was taken at a buritizai in the lavrado in Northern Brazil.

Fig. 50: Giant anteater having a bath in a buritizai in Northern Brazil, grooming his fur in the water.
During three observations before entering the riparian zone, anteaters foraged for between two and seven minutes along the border where savanna vegetation meets the riparian of the buritizais. Along this border beaten paths used by many different animals could be found. Tracks and faeces of deer were found in large quantities as well as tracks of capybaras (*Hydrochoerus hydrochaeris*) and giant anteaters (fig. 51, photos A & C). Footprints of capybaras could be found frequently in and around the drainage channels as well (fig. 51, photo B).

Fig. 51: Animal signs along the border to the riparian zone in the savanna of northern Brazil. A = Paths with footprints of different animals. B = Footprint of Capybaras. C = Faeces of Deer.
2.2 Defecation behaviour

Giant anteaters’ faeces showed a clustered distribution influenced by the home ranges of the animals (fig. 52).

Fig. 52: Distribution of giant anteater faeces within their home ranges in plantations of *Acacia mangium* in Northern Brazil.

Every third tree row within the plantations in the study area was surveyed for scat of giant anteaters. Altogether 56 faecal deposits were found and their location recorded with the GPS. The scat distribution was analysed by means of a nearest neighbour index (NNI) and was found to be significantly clustered (NNI = 0.35 (values < 1 represent clustering); Z = -9.91; p < 0.01). Because discrete sites with accumulations of faeces are defined in the literature as “latrines” (Gorman & Trowbridge 1989, Roper et al. 1993) I will subsequently use this term for spots containing more than one scat. Faeces was assigned to a latrine when the maximum distance to the next scat was less than eight meters. I chose an eight meter limit because distances to other scats were found to be eight meters or less (minimum: 20cm) or more than 15 meters (maximum: 300 meter to next scat). Within the study area 20 spots with faecal deposits were located. Eleven scats were found to be separated from other scats.
Additionally nine latrines with a minimum of two and a maximum of ten scats were detected (tab. 8). Faecal density in the latrines was $0.92 \pm 0.8$ scats per meter (minimum 0.18 scats per meter, maximum two scats per meter). However within the latrines there were areas with up to four scats in an area of 0.2 m² (fig. 53).

<table>
<thead>
<tr>
<th>No. of scats per spot</th>
<th>Frequency (n)</th>
<th>No. of overlapping MCPs (mean ± SE)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>11</td>
<td>2.0 ± 1.1</td>
</tr>
<tr>
<td>2</td>
<td>2</td>
<td>3.0 ± 1.4</td>
</tr>
<tr>
<td>3</td>
<td>1</td>
<td>2.0 ± 0</td>
</tr>
<tr>
<td>4</td>
<td>2</td>
<td>2.5 ± 0.7</td>
</tr>
<tr>
<td>5</td>
<td>3</td>
<td>3.7 ± 0.6</td>
</tr>
<tr>
<td>10</td>
<td>1</td>
<td>4.0 ± 0</td>
</tr>
</tbody>
</table>

Fig. 53: Latrine with faeces of giant anteaters in plantations of *A. mangium* in Northern Brazil. The faeces are of different age: 1 = newest-, 4 = oldest scat.
I also determined whether there was a connection between the numbers of scats per spot and the number of anteater home ranges that overlapped at this location (tab. 8). A Spearman rank correlation showed that the more home ranges are overlapping each other, the more scats are clustered in those areas (fig. 54).

![Fig. 54: Significant correlation between the number of giant anteaters' scats clustered at distinct spots and the number of home ranges (MCPs) of the animals that are overlapping these. Data collected in plantations of *A. mangium* in Northern Brazil.](image)

I further compared scat densities in areas with different numbers of overlapping home ranges of giant anteaters. To determine whether the number of scat per hectare increased proportionally with the number of overlapping home ranges I calculated expectation values for a proportional increase and compared them with the measured densities. It could be shown that in areas where four anteaters had their home range, there was an un-proportionally high rise of scat densities (fig. 55).
During my study it could not be determined, whether the faeces within latrines were of individual animals or of multiple animals. I did not conduct detailed analysis of the composition of anteater scat, but during visual examinations in the field I recognised sand and ant bodies within them. One scat contained soft shells of reptile-eggs with a length of approximately 1 cm (fig. 56).

Figure 53 shows that scats within a latrine were of different ages. The approximate age could be determined by means of the degree of degradation.

On two occasions in my study period defecating giant anteaters were observed directly: once in the plantation by a foraging animal and once dropped in the water of one of the drainage channels. In both cases no other scats were found nearby. To determine the speed of degradation, I took photographs of the fresh droppings in the plantation and the water less than five minutes after observing the anteater.
defecating and another picture of the same scat three days later (fig. 57). After three days the scat in the water was not recognizable anymore, while faeces within the plantation showed a much slower degradation process, although ants in the plantation began scattering it immediately after the anteater produced it.

![Fig. 57: Degradation process of faeces of giant anteaters in Northern Brazil. Photo A shows fresh faeces in an *Acacia mangium* plantation less than five minutes after dropping, photo B shows the same droppings three days later. Pictures C and D also show the degradation process over an interval of three days, this time in the water of a drainage channel near the plantations in the open savanna. The arrow marks ants at the fresh dropping already beginning the degradation process.](image)

After my observation of the anteater defecating in the water, I searched this south eastern channel for faeces. I could find two spots, each with one scat. Due to the different degradation speed, the numbers of scats detected were expected to be lower in the water than in the plantations. It was not possible to scan for scat at other water sides because of the dense understorey, mud and/or deeper water.

The observation of the defecating anteater in the drainage channel opened up further aspects of the defecating behaviour of giant anteaters: The anteater first walked along the drainage channel in the water while drinking repeatedly. It then stopped in the middle of the channel in shallow, stagnant water, raised the tail and defecated into the water. During defecation it continued drinking. After defecating it turned around immediately and drank at the spot where the droppings were (fig. 58).
Fig. 58: Giant anteater defecating in a drainage-channel in the savanna in Northern Brazil (A). At the same time as the animal defecates into the water, it drinks from it (B). After defecation it turns around to drink from the water directly next to the droppings (C).
2.3 Scratching behaviour

*GPS recording of all scratching tree positions within the core area of my study site:* Scratching trees within the core area of my study site were very common and had a clumped distribution.

Every row of trees within the core area of the plantation was surveyed to locate trees with scratch marks of giant anteaters. All in all 1483 trees with marks were found in an area of 73 ha. The distribution of scratching trees was analysed by means of the nearest neighbour index (NNI) and was found to be significantly clustered (NNI = 0.05 (values < 1 represent clustering); Z = -69.95; p < 0.01). Mean scratching tree density over the whole area was 10 trees per ha. A fixed kernel density estimation revealed that in some areas scratching trees were considerably more common than in the rest of the study site. Percent volume contours were created, one representing 50% and the other one 95% of the probability density distribution volume (fig. 59). It could be shown that scratching tree density was nearly three times higher in the 50% core areas than in the remaining part of the study site (tab. 9).

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**Fig. 59:** Fixed kernel density estimation for the distribution of scratching trees of giant anteaters in plantations of *Acacia mangium* in Northern Brazil. The red contour outlines 50% and the black contour 95% of the probability density distribution volume.
Tab. 9: Comparison of scratching-tree distributions in 50% volume core-areas and the area in-between the 50% contour and the 95% contour. Data collected in A. mangium-plantations in Northern Brazil.

<table>
<thead>
<tr>
<th>Percent Volume Contours</th>
<th>size (ha)</th>
<th>No. scratch-trees</th>
<th>% of all fixes</th>
<th>Mean density scratch-trees per ha</th>
</tr>
</thead>
<tbody>
<tr>
<td>Area within 50% contour</td>
<td>31</td>
<td>868</td>
<td>59</td>
<td>28</td>
</tr>
<tr>
<td>Area between 50% and 95% contour</td>
<td>62</td>
<td>601</td>
<td>41</td>
<td>10</td>
</tr>
</tbody>
</table>

To determine whether the observed use of home ranges influenced the scratching tree distribution, I compared the 50% core area for the scratching tree fixes with that of the independent giant anteater points (fig. 60). There was approximately 30% overlap between the two areas (the 50% scratching tree contour was overlapped by the 50% giant anteater contour by 35%; conversely, the scratching tree contour overlapped the giant anteater contour by 32%). Hence, the core area positions differed to a large extent.
I further determined the scratching tree density in areas with different numbers of overlapping home ranges of giant anteaters. The density of scratching trees increased with the number of overlapping home ranges in the study area. As with the scat density I determined whether or not the density of scratching trees increased in proportion to the number of giant anteaters in the area. It could be shown that the number of scratching trees increased proportionally to the number of anteaters in the area (fig. 61).

Comparing scratching tree distributions with the distribution of giant anteaters is considered problematic. The giant anteater fixes I collected showed the distribution of the animals during my study period, while the recorded scratching trees included trees with older marks as well as those with new scratches. They therefore did not necessarily reflect the distribution relevant to the study period. Additionally, anteaters were spotted by car observation and inspecting the plantation from the road led to an over sampling of the border areas. Conversely, scratching trees were mapped by pacing the plantation rows and recording all scratching trees in the study-area.
**Behavioural observations of scratching tree behaviour:**

Anteater GA7 was only located once in my study period. At this single observation it was resting and no further behavioural observation was conducted. Though, it will not be respected in the following. Anteater GA8 was as well only observed on a single day. During this observation it displayed (compared to the other anteaters) outstanding high numbers of tree interactions in form of scratching and sniffing. Therefore with the results for this animal will be deleted separately and I will firstly present the results for anteaters GA1 to GA6.

All in all, giant anteaters were observed sniffing or scratching at trees 43 times. These actions were not evenly distributed over the observation days. Only on a mean of 27 ± 19% of the days the individuals were observed did interactions with trees occur. GA1 showed the most interaction with trees with 50% of the days it was observed and GA6 was never observed sniffing or scratching at trees (fig. 62). On 65% of the days on which scratching or sniffing by an individual was observed, interactions occurred more than one time, reaching up to a maximum of nine interactions on a single day displayed by GA3. Therefore the different individual frequencies of scratching and sniffing, illustrated in figure 62 were highly dependent on the number of days and the duration that the individuals were observed.

**Observed behaviour:**

1. **Sniffing:** sniffing at trees was observed 34 times during my study period over a total of 35 hours of behavioural observations. It could be seen in twelve observation units of individual anteaters. Nine of those twelve observations in which sniffing occurred took place in the mornings between 8:00 and 10:00. The anteaters would pass trees during foraging, stop suddenly and begin sniffing. Firstly they would sniff rapidly from the base to higher up the tree trunk and then longer and more intensively, often with audible snuffling sounds, at a certain spot. On 28 occasions obvious scratching marks could be detected on the trunk. In these cases, anteaters were observed to sniff directly at the scratching marks eight times while in 14 cases they were observed sniffing 30 to 40 centimetres below the scratch marks (fig. 63). On the other occasions it was not possible to see clearly if the anteater sniffed at the scratching marks or not. In one observation an anteater could be witnessed sniffing at a palm tree next to a buritizai (fig. 64). In all cases there was no apparent evidence that anteaters went out of their way to sniff at a specific tree ( fig. 65).
Fig. 62: Locations in plantations of *Acacia mangium* in Northern Brazil where individual giant anteaters (GA1–GA5) could be observed scratching or sniffing at trees. Light grey surfaces mark home ranges (MCPs) of sympatric giant anteaters that are overlapping each other. GA6 is not represented with a map, because it showed no tree interactions.
Fig. 63: Giant anteaters sniffing at trees of *Acacia mangium* with obvious scratching marks (arrows) in plantations in Northern Brazil. In the right picture the animal sniffs directly at the scratches, in the left picture it sniffs 30 to 40 cm beyond those marks.

Fig. 64: Giant anteater sniffing at a palm tree in the North Brazilian savanna.

Fig. 65: Giant anteaters sniffed frequently at trees within a plantation of *Acacia mangium* in Northern Brazil. The figure displays an example of the position of sniffing trees within the path of a giant anteater. The animals did not seem to head purposefully towards certain trees.
2. Scratching trees: To “scratching trees” all behaviours are counted that were observed to result at least in many cases in scratching marks. Scratching at trees was observed seven times during my study period and occurred throughout the day without noticeable temporal patterns. On four of those trees existing scratch marks had been detected before the observed scratching. In all cases the anteaters sniffed at the trees before they started scratching. Two different kinds of tree scratching postures could be distinguished:

- Standing posture: in five of the seven observed cases the anteater stood up against the tree, subsequently clasped the trunk with one or both forelegs, rubbed its chest on it and using its fore claws, scratched at the bark on either side of its head or on the opposite side of the trunk. In the clearest observation of this behaviour the animal clasped the trunk only with one foreleg while with the other one it scratched the tree-bark next to its head very gently. The tree showed no scratching marks before or after scratching (fig. 66). In two other observations an anteater stood up and scratched at a tree that had already showed before numerous long and deep scratches (fig. 68). On these occasions the animal embraced the trunk with both fore legs, scratching with both claws at the bark on the opposite site.

- Climbing posture: The climbing posture appeared to be an enhancement of the upstanding posture. The anteater first stood up against the tree and embraced it like displayed in the upstanding posture. But this time it subsequently climbed the trunk using all four legs until it reached a position of more or less 50 cm above the ground (fig. 67). Then it began rubbing the ventral side of its body at the tree for approximately ten seconds. After that it climbed down again. The climbing posture was observed two times.

When an animal was observed to scratch a tree I subsequently tried to locate the trunk to scan for fresh scratching marks. I succeeded in three of the cases and found that two of the trees displayed fresh scratch marks. One of those trees was observed to be scratched with the upstanding posture, the other one with the climbing posture. The fresh scratch marks were all very short and small. New marks can be distinguished from older marks due to the red colour of freshly ripped bark. Older signs have a pale brown colour (personal observations based on the 2005 pilot study).
Except for one occasion the animals did not seem to leave their foraging path to reach a tree for scratching. The only time an anteater was observed to head directly towards a tree and then scratch it was during an observation of GA3. The anteater traversed the savanna in the direction of the talhãos in the border area. It crossed the drainage channel and as it arrived at the first talhão it marked a tree on the very outermost corner which already showed various scratching marks (fig. 68). Marking was conducted in the standing posture. After that it returned to the drainage channel, followed it for a couple of meters and then headed to the next talhão (fig. 68).
Part I Results

Fig. 67: Giant anteater (GA8) scratching at a tree and rubbing its ventral side against it. The anteater climbs up approximately 50 cm. Photo taken in plantations of *Acacia mangium* in Northern Brazil.

Fig. 68: Giant anteater scratches at a tree in plantations of *Acacia mangium* in Northern Brazil (left photograph). It seemed as though the anteater approached the tree directly, due to the remarkable change of direction (see path, map). The tree was positioned at the border where the plantation meets the open savanna (red arrow, map) and already had conspicuous scratching marks (picture right). After scratching small, fresh marks could be detected that possibly resulted from the observed scratching activity (white arrow, small picture right).
GA8 was seen for the first time in my study area on the very last observation day when I followed it for 57 minutes. It ranged within the part of the plantation where GA2 had its home range. The animal displayed an outstanding intensity of foraging behaviour, remaining at single spots for up to five minutes digging deep holes in the ground\(^4\) (fig. 69). Additionally an unusually high number of interactions with trees were observed.

GA8 sniffed nine times at several trees. Scratching was observed six times (in comparison the other anteaters were seen scratching seven times in 35 hours; tab. 10). In these six scratching events GA8 used the standing posture two times and the climbing posture four times (fig. 70).

Tab. 10: Observed tree interactions (sniffing and scratching) and frequencies of giant anteaters (GA) in Northern Brazil.

<table>
<thead>
<tr>
<th>ID</th>
<th>total observation time</th>
<th>No. of tree-sniffing</th>
<th>No. of tree-scratching</th>
<th>tree-sniffing per hour</th>
<th>tree-marking per hour</th>
</tr>
</thead>
<tbody>
<tr>
<td>GA1</td>
<td>14:53</td>
<td>19</td>
<td>1</td>
<td>1.3</td>
<td>0.1</td>
</tr>
<tr>
<td>GA2</td>
<td>3:47</td>
<td>1</td>
<td>0</td>
<td>0.3</td>
<td>0.0</td>
</tr>
<tr>
<td>GA3</td>
<td>14:20</td>
<td>9</td>
<td>4</td>
<td>0.6</td>
<td>0.3</td>
</tr>
<tr>
<td>GA4</td>
<td>2:49</td>
<td>2</td>
<td>2</td>
<td>0.7</td>
<td>0.7</td>
</tr>
<tr>
<td>GA5</td>
<td>2:03</td>
<td>3</td>
<td>0</td>
<td>1.5</td>
<td>0.0</td>
</tr>
<tr>
<td>GA6</td>
<td>1:36</td>
<td>0</td>
<td>0</td>
<td>0.0</td>
<td>0.0</td>
</tr>
<tr>
<td>GA8</td>
<td>00:57</td>
<td>9</td>
<td>6</td>
<td>9.5</td>
<td>6.3</td>
</tr>
</tbody>
</table>

\(^4\) The mean observed duration of a feeding bout in the plantation is 14.4 ± 10.9 sec (Kreutz 2007).
Part I Results

3 Nutrition of giant anteaters
Altogether 41 feeding signs of giant anteaters in the core area of my study site were sampled. The majority of samples contained ant nests. In the remaining signs nests of termites were found and in and around a single feeding sign small reptile eggs with a diameter of approximately one centimetre were seen. Three of these eggs had been destroyed and two remained intact (fig. 71).

The ants could be classified in seven different genera (tab. 11). Every feeding sign contained only one genus of ants, except of one in which three different ant genera could be distinguished and another one where additionally a species of termites could be located. Camponotus sp. was the genus that could be collected most frequently from feeding signs, followed by Dorymyrmex sp.
Two families, three subfamilies and four morphospecies of termites could be distinguished. In two feeding spots two different morphospecies could be determined. Altogether 18 feeding signs contained termites (tab. 12), most of them belonging to the morphospecies Anoplotermes.

Fig. 71: Numbers of feeding signs in which nests and specimens of ants or termites could be identified. In one case small reptile eggs were found in and next to a feeding sign. Data collection took place in plantations of *Acacia mangium* in Northern Brazil.

<table>
<thead>
<tr>
<th>Genus</th>
<th>No. of locations</th>
</tr>
</thead>
<tbody>
<tr>
<td><em>Dorymyrmex sp.</em></td>
<td>6</td>
</tr>
<tr>
<td><em>Camponotus sp.</em></td>
<td>9</td>
</tr>
<tr>
<td><em>Wasmannia sp.</em></td>
<td>2</td>
</tr>
<tr>
<td><em>Paratrechina sp.</em></td>
<td>2</td>
</tr>
<tr>
<td><em>Pheidole sp.</em></td>
<td>2</td>
</tr>
<tr>
<td><em>Brachymyrmmex sp.</em></td>
<td>4</td>
</tr>
<tr>
<td><em>Crematogaster sp.</em></td>
<td>1</td>
</tr>
</tbody>
</table>
4 The influence of thinning on the distribution of scratching trees

With an extent of together 7.5 hectares, the two sampled talhãos were very small. Before thinning 176 scratching trees could be recorded after thinning only less than a third remained. After six weeks the number of scratching trees was 8.6% higher than directly after thinning (tab. 13; fig. 72).

The core areas that contain 50% of the probability density distribution volume showed differences especially in their extent before and after thinning, but the position of those areas were nearly identical as could be shown by overlaying the two contours (fig. 73).

Tab. 12: Families and morphospecies of termites consumed by giant anteaters in plantations of *Acacia mangium* in Northern Brazil.

<table>
<thead>
<tr>
<th>Family</th>
<th>Subfamily</th>
<th>Morphospecies</th>
<th>Frequency</th>
</tr>
</thead>
<tbody>
<tr>
<td>Termitidae</td>
<td>Apicotermitinae</td>
<td><em>Anoplotermes</em></td>
<td>10</td>
</tr>
<tr>
<td>Termitidae</td>
<td>Nasutitermitinae</td>
<td><em>Nasutitermes</em></td>
<td>2</td>
</tr>
<tr>
<td></td>
<td></td>
<td><em>Velocitermes</em></td>
<td>3</td>
</tr>
<tr>
<td></td>
<td></td>
<td>not identified</td>
<td>1</td>
</tr>
<tr>
<td>Rhinotermitidae</td>
<td>Heterotermitinae</td>
<td><em>Heterothermes</em></td>
<td>1</td>
</tr>
<tr>
<td>Termitidae</td>
<td>Not identified</td>
<td>-</td>
<td>3</td>
</tr>
</tbody>
</table>

Tab. 13: Numbers of scratching trees of giant anteaters in plantations of *Acacia mangium* before the area was thinned, directly after thinning and six weeks after thinning.

<table>
<thead>
<tr>
<th></th>
<th>Number</th>
<th>Density</th>
<th>Percent</th>
</tr>
</thead>
<tbody>
<tr>
<td>Unthinned</td>
<td>176</td>
<td>23.5</td>
<td>100</td>
</tr>
<tr>
<td>Thinned week 1</td>
<td>52</td>
<td>6.9</td>
<td>29.5</td>
</tr>
<tr>
<td>Thinned week 6</td>
<td>67</td>
<td>8.9</td>
<td>38.1</td>
</tr>
</tbody>
</table>
Fig. 72: Fixed Kernel Density Estimations representing the scratching tree densities before and directly after thinning. The red contours show the core areas which contain 50% of the probability density distribution volume.

Fig. 73: Overlap of the core areas that contain 50% of the probability density distribution volume.
Considering the shape, the majority of scratching trees was inclined or very inclined before thinning (fig. 74). I showed in my study about scratching trees of giant anteaters in 2005, that most of the trees in the plantation have straight trunks and that the anteaters choose trees with an inclined shape. After thinning the majority were still inclined trees but of the very inclined trees only few were left. After six weeks the number of very inclined trees still had not increased, while the other categories displayed a marked accession. Especially the proportion of straight scratching trees increased for nearly 50%.

It was tested with Pearson's $X^2$ test if the shapes of the scratching trees differed significantly before and after thinning. It could be shown, that one week after thinning the shape of the scratching trees was significantly different. After six weeks this difference became highly significant (tab. 14).

Fig. 74: Numbers of scratching trees of giant anteaters with different shapes before, directly after and six weeks after thinning. White bars: straight trunks (0° - 5° from plumb line), dotted bars: inclined trunks (5° - 15° from plumb line) and black bars: very inclined (>15° from plumb line). Data collected in plantations of *A. mangium* in northern Brazil.
Tab. 14: Comparison of the shape of scratching trees\(^1\) before thinning with the week after thinning (week 1) and six weeks after thinning (week 6) by means of Pearson’s \(X^2\) test.

<table>
<thead>
<tr>
<th></th>
<th>before / week 1</th>
<th>before / week 6</th>
</tr>
</thead>
<tbody>
<tr>
<td>(X^2)</td>
<td>6.17</td>
<td>12.17</td>
</tr>
<tr>
<td>df</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>(p)</td>
<td>0.05</td>
<td>0.002</td>
</tr>
<tr>
<td>significance</td>
<td>*</td>
<td>**</td>
</tr>
</tbody>
</table>

\(^1\) straight, inclined, very inclined
IV DISCUSSION

There is little literature in existence concerning the ecology and behaviour of giant anteaters in the wild. I present below a short review of important field studies on this topic that will be cited repeatedly in the following discussion:

Two studies were conducted in 1977 and 1985 about movement and food habits of giant anteaters on a cattle ranch in the llanos, a temporary flooded savanna in Venezuela (Montgomery & Lubin 1977, Montgomery 1985). In these studies the animals were tracked using radio-telemetry. Published in 1985 and 1987 Shaw et al. gave an overview about giant anteater’s foraging patterns, population structure, organization and behaviour within the Serra da Canastra national park in Minas Gerais, Brazil. The study was conducted partly by means of radio-telemetry and partly by direct observation. In his studies of 1985 and 1986 Redford examined the food preferences of giant anteaters. The first part of his study in 1985 took place in the Emas National Park in Central Brazil by means of a car-based survey and direct behavioural observations. The results were compared in the second part of his study with food preferences of animals in the zoo of Brasilia. In recent times there have been some publications about giant anteaters in the Pantanal wetland in Brazil, all conducted by means of radio-telemetry. Medri & Mourão determined home range and habitat use of giant anteaters in 2005, a further study in 2006 dealt with the responses of giant anteaters to ambient temperature (Camilo-Alves & Mourão) and the most recent study thematized activity patterns (Mourão & Medri 2007).

All of the studies mentioned were conducted in open or semi-open grass or shrub land. In 2007 Kreutz carried out his studies about the giant anteaters in the Acacia mangium plantations of the Ouro Verde Ldta. in northern Brazil where also my study took place. He determined densities and habitat preferences of giant anteaters in and around the plantations focussing on the influences of plantation management on the animals. I conducted a study within the plantations in 2005 that concentrated on the use of scratching trees by giant anteaters and the implications for social organization (results in Kreutz 2007). The studies by Kreutz and myself are the first surveys that focus on a (albeit artificial) forest habitat.
1 Spatial and social organization

Anteaters in my study site appeared in high densities, with small home ranges that were overlapping each other to a large extent.

Home range in literature: ‘Home range’ is referred to in the literature as the area used by an animal (Burt 1943). Its size is dependent upon the distribution of resources like food, mating opportunities and habitat features (Fischer & Linsenmair, 2001). In recent times the established method employed to determine home range use is radio-telemetry, a very efficient opportunity for monitoring movement patterns of animals. Though I did not have the possibility to monitor the anteaters with radio-telemetry, I wanted to conduct a pilot study to gain initial insights into the spatial and social organization of giant anteaters within the plantations. This was of special interest due to the outstandingly high abundances of the animals within the plantation. I therefore developed an efficient approach for an inexpensive short-term analysis of the giant anteaters’ home range use without using telemetry.

Home range sizes of giant anteaters in literature refer mainly to the Minimum Convex Polygon method and vary remarkably depending on the geographical location. Giant anteaters in Venezuela were reported to have a home range size of 2500 ha (Montgomery & Lubin 1977). In 1987 Shaw measured a home range size of 370 ha for adult females and 270 ha for adult males for giant anteaters in the Serra da Canastra. This corresponds to approximately 10% of the size Montgomery reported. In the Pantanal, home range sizes of 570 ha for adult males and 1190 ha for adult females were determined (Medri & Mourão 2005). In all those studies the animals were radio-collared and monitored for six to eight months by telemetry.

Home ranges and densities in my study site: Respecting the independent fixes, I measured a mean MCP size of 44 ha which was remarkably small compared to the estimated home ranges of other studies. Due to my method of data collection I assume that the MCPs obtained are considerably underestimated and that observed variations among home ranges result from the different numbers of sighting events of individual animals. Therefore I developed a function (page 22) to compensate that bias. It calculated the proportion of days the animal was presumably outside my study site out of all days the animal could not be located during my study. This value multiplied with the mean accumulation rate of an animal’s home range makes the area that was presumably missing in my measured MCP. The variations among the
calculated MCPs were considerably lower and the mean home range size calculated with the function on the basis of the collected data was 135 ha. Though this surely cannot be regarded as a definite value of home range size I consider it to be a good approximation. This is affirmed by data of Kreutz in 2007. In his study he conducted car based observations in the whole plantation of the Ouro Verde Ldta. and the distances between multiple sightings of individual anteaters were only in one case larger than 1.6 km. This speaks for a mean home range size of 160 ha or less, which comes very close to the size of my hypothetical MCP. The method of data collection without radio telemetry and afterwards calculating an approximated MCP might be an efficient method for similar short-time studies of other species where there is not the possibility of using telemetry for home range estimation. It should be tested for functionality in further studies that allow the comparison between home range estimations with data obtained by radio-telemetry and the hypothetical MCP calculated with my function.

Even the maximum estimation of a home range size of 160 ha for the plantation is still considerably lower than the minimum value of 270 ha obtained by Shaw for adult male giant anteaters. This could result from the fact that my study period was shorter than that of Shaw. The accumulation curves did not reach the asymptote and possible changes in home range use over the seasons are not considered as the study took place exclusively during the summer months. Another possibility is that the animals live closely spaced inside the plantation due to the optimal conditions for the species.

Throughout the literature, authors report that giant anteaters are nowhere abundant, though there are only scarce estimates of giant anteater population sizes or densities (Shaw et al. 1987, Miranda 2004). Densities of giant anteaters are reported to be high in the Serra da Canastra National Park with 0.13 anteaters per ha (Shaw et al. 1987). In the Emas National Park densities of 0.04 anteaters per ha were found (Miranda 2004). Kreutz determined for the plantation of the Ouro Verde Ldta. a mean density of 0.32 individuals per ha. This is threefold the value of the highest densities reported by Shaw et al.. For my study area I observed even higher densities with 0.65 animals per ha.

As I will show further on in the discussion, food supply and habitat heterogeneity provide optimal conditions for giant anteaters within the plantations, leading to a high preference for this habitat. Because home range sizes have to be large enough to
include sufficient food to meet energy requirements (Goodrich & Buskirk 1998) the home ranges in areas with a good food supply are expected to be smaller than in areas were only little food is available. The plantations appear to be an extremely good foraging ground for the animals compared to their natural savanna habitat. Therefore the home ranges are expected to be smaller than MCP-sizes that were estimated in studies undertaken in savannas and open grasslands. Furthermore, different habitat features occur in my study area in close proximity to each other what relieves the anteaters from the need to cover long distances to reach certain required habitat types like riparian zones. Finally, the high densities of the animals in the study area means that the search for mating partners that may lead to dispersal and larger home ranges can be conducted over a smaller area.

In summary the anteaters within my study area appear to be relatively small home ranges that meet their demands for food, mating partners and habitat types. It can be assumed that the large numbers of conspecifics sharing a relatively small area require an efficient system of spatial organization for a solitary animal like the giant anteater. Three reports about agonistic encounters between two animals can be found in literature (Shaw et al. 1985, Rocha & Mourão 2006, Kreutz 2007), leading to the assumption that acceptance of others among conspecifics is not very high and that there has to be a system of avoiding encounters with other anteaters.

**Spatial organization:** Solitariness and its inverse, gregariousness, are quantifiable in terms of the proportion of time that animals are alone or together with conspecifics. (Wiens & Zitzmann 2003). I never saw two individual giant anteaters interacting directly with each other. Anteaters did not seem to defend territories and no agonistic encounter was observed. Only in two cases could two animals be seen foraging in the same part of the plantation and the observation of an anteater running away after noticing another supports the assumption of low acceptance between conspecifics. Nevertheless, home ranges among individuals overlapped to a large extent. Some home ranges were nearly completely overlapped by up to four other MCPs. By means of the Kernel Density Analysis it could be shown that even the high use areas within individual home ranges are overlapping each other.

The plantation situated in my study area appeared to be completely homogenous. In a homogenous habitat one would expect a scattered distribution for a solitary animal especially in an area with such outstanding high densities. This was not the
case in my study area. I could show that some parts of the site were used intensively by several animals while other parts were nearly unused. In this study I could not determine any reasons for this clumped distribution but it emphasizes the need of the animals for an efficient system of spatial-organization to regulate space use and to avoid other individuals.

Two behavioural patterns were observed that are supposed to play a role in spatial organization among individual giant anteaters:

1. *Defecation behaviour*: This is the first study of giant anteaters that determined distribution patterns of scat in giant anteaters. The faeces showed a clustered distribution and there were a number of small areas with large amounts of scat. Such discrete sites with accumulations of faeces are defined in the literature as latrines and they often play an important role in the context of social organization in a number of species (e.g. ferret (*Mustela furo*), Clapperton 1989; brown hyena (*Hyaena brunnea*), Gorman 1990; badgers (*Meles meles*), Roper et al. 1993).

Many mammals, especially carnivores, use faeces to mark their territories (Gormann & Trowbridge 1989). Due to the extent of home range overlap, I do not suppose giant anteaters in my study area to be territorial and therefore I disclaim a function of latrines for territory defence. The numbers of faeces were observed to rise nearly exponentially with the number of overlapping home ranges. In areas with four home ranges overlapping each other the density of faeces was more than twenty times higher than in areas with only one anteater. Additionally the numbers of scat per latrine increased with the numbers of overlapping home ranges. Therefore I presume that faeces do play a role in the intraspecific communication of giant anteaters. Indirect, olfactory communication by latrines or other scent marking systems with relevance beyond territory defence is a typical attribute of solitary mammals (e.g. brown hyenas, Gorman & Mills 1984; klipspringer (*Oreotragus oreotragus*), Roberts 1997; honey badger (*Mellivora carpensis*), Begg et al. 2003; giant pandas (*Ailuropoda melanoleuca*), White et al. 2002 & 2003). These animals are in need of an effective communication system to maintain social organization and ensure reproductive success (Delahay et al. 2007).

For such a solitary animal like the giant anteater with its good olfactory senses, latrines could be an instrument of communication for exchanging information about individual identity, status, home range use and mating partners. This is the first
description of such behaviour of giant anteaters in the literature and its implications for social and spatial organization should be determined in further studies. Additionally a comparison of latrine use in low density populations in natural habitats with the here investigated high density population in the plantation would be interesting. The complexity of the scent marking system in beavers for example (*Castor Canadensis*, Müller-Schwarze & Heckman 1980) is highly dependent on population density.

The use of small, discrete sites for depositing scat implies additionally that anteaters have very detailed orientation within their home range. Re-finding such latrines in the apparently homogenous plantation environment is, even for an animal with a very good olfactory apparatus, a challenge.

2. **Scratching behaviour:** It is possible that the numerous scratching trees that can be found in the plantation support the orientation of the animals in their environment. In 2005 I identified trees in the plantation that displayed conspicuous scratch marks of giant anteaters. I showed that anteaters chose trees for scratching that had a certain shape and differed in several characteristics from other trees within the study area. Behavioural observations of giant anteaters rubbing their chest or the urogenital-tract on the trees led me to the assumption that the animals apply secretions on the trees (though I never found visible vestiges of secretion on freshly marked trees). The scratching behaviour is not supposed to occur only to sharpen the claws. If it was so, the anteaters would not sniff frequently at trees that display scratching marks and additionally they would not climb the trees, which is a behaviour with presumably high energy costs. I consequently assumed that the function of this behaviour is primarily for depositing scent marks. I supposed that the scratch marks function as additional visual cues, increasing the probability of locating by the receiver (Möcklinghoff unpublished results, Kreutz 2007). Scent marking at conspicuous sites is, for example, known for the klipspringer that also marks trees with a certain shape (Roberts 1997).

The deposited scent marks could function as landmarks for the orientation of the animals. Because the visual and acoustic senses of giant anteaters are poorly developed and they are very macrosomatic animals (McAdam & Way 1967) it is likely that they orientate by means of olfactory cues in their environment. Slow loris for example deposit scent marks for the orientation in their home range (*Nycticebus*...
couchang, Seitz 1969) during normal foraging activity. This results in a gradient, with a higher frequency of marks in the centre of the home range and decreasing towards the edges. The density of scratching trees was higher in the centre than on the edge of the plantation, a possible hint that scratching trees play a role in the orientation of giant anteaters.

The distribution of scent marks in an animal’s home range often provides information about its meaning for the animal. Scratching trees that function in the context of territorial defence or to keep discrete sites free of conspecifics would be for example expected to be located at the boundaries of the hinterland of the home range (e.g. at the boundaries, Gormann & Trowbridge 1989). My collected data did not provide any information about scratching tree distribution within the home ranges of individual anteaters. I could not obtain the complete extent of the animals’ ranges with reliably defined boundaries. Additionally linking the distribution of marked trees with the anteaters’ distribution is problematic with my data. The scratching trees do not provide information about the current situation because old and fresh marks were recorded, while the anteater distribution only gives the actual status. Nevertheless, I presume that anteaters do not use defined spots in their home range for marking. During the direct observations, the animals appeared to scratch or sniff at trees they encountered 'accidentally' when foraging. They were almost never observed to walk straight to remotely situated scratching trees.

In other carnivores scent marks have been shown to provide temporal information on space use and animals avoided using areas that had been recently marked by conspecifics (Clapperton 1989, Gorman & Trowbridge 1989). In this case, exclusive land use is not maintained by delimited areas belonging to individual animals, but by using certain sites at different times. Scent marks function as a kind of ‘traffic light’, with fresh marks telling other conspecifics: ‘Stop, I am already here!’ and older marks signaling a lower risk of encountering another individual (as shown for the domestic cat (Felis silvestris f. catus), Leyhausen & Wolff 1959).

What questions this as well as the function of scratching trees for orientation, are the scarce numbers of giant anteaters that could be directly observed while marking. Considering the high number of trees in the plantation and the low scratching frequency the probability of anteaters encountering fresh marks is low.
In the following I want to develop a hypothesis of social organization in high density populations of giant anteaters. Potentially the home ranges of anteaters are relatively stable, so that neighbouring animals are well coordinated and the number of overlapping home ranges is balanced with the food supply. An adjusted space use system like this would reduce the need for a high marking frequency. ‘Social units’ among solitary animals are for example known for most solitary prosimians like the slow loris and refer to relatively stable groups, with individual home ranges of animals of the same unit overlapping each other (Müller & Thalmann 2000, Wiens & Zitzman 2003). In literature this phenomenon is also referred to as ‘spatial groups’ (Macdonald 1983) or ‘dispersed social systems’ (Müller & Thalmann 2000). Slow loris do not usually show aggressive behaviour to conspecifics of the same unit but rather to neighbouring individuals of other spatial groups.

In the literature encounters between giant anteaters are reported to be aggressive, but there are also several observations of animals encountering conspecifics without showing aggression, sometimes sniffing at each other and afterwards foraging or walking off in different directions (pers. obs., Shaw 1985, Rocha & Mourão 2006, Kreutz 2007). Sex of the animals involved could not be determined in any of these observations and could be the crucial factor that decides if aggression occurs or not. However, the observations fit well to those observed between spatial groups of slow lorises.

Of interest was the observation of one anteater showing extremely high scratching frequencies. This individual was seen for the first time in the study area and appeared to be very alert, frequently sniffing in the air. This behaviour is always a sign of increased attention in anteaters (pers. obs., Kreutz 2007). Furthermore, through the whole observation its fur was piloerected which is a behaviour usually only displayed when the animals are scared or disturbed (pers. obs.). Going back to my hypothesis, this animal could have been an intruder that entered the area of a foreign spatial group, displaying frequent marking behaviour to inform the residents about its presence, identity and status.

In this scheme scratching trees could function as an orientation system for the animal itself and in the same time as signals for intra- and inter-group communication for example about the spatiotemporal distribution of the animals.
Part I  Discussion

Such an arrangement of giant anteaters in social units remains just a hypothesis in this study, but it is a possible explanation of the observed intra-specific interactions and should be considered in further studies of the social organization of the animals.

Future studies should also investigate how animals are organized in grasslands and open savannas where trees for scratching are scarce (at least in the savannas of Roraima) and the densities of the animals are clearly lower.

**Scratching trees and thinning:** To increase wood production, thinning is effected once in every plantation unit. Thinning is a management procedure where dead and not promising trees as well as all trees of the species *A. auriculiformis* are cut down and afterwards left within the plantations. After the thinning procedure the number of scratching trees was remarkably reduced. The distribution of areas with the highest density of scratching trees in the study site was mainly the same before and after thinning.

Before the procedure, the shape characteristics of marking trees was the same as determined in 2005, with inclined or very inclined trees being preferred for scratching. In the course of the thinning procedure inclined trees are selectively cut out and this was reflected in the change in the proportions of inclined and straight scratching trees. After six weeks this difference had grown in significance, because the number of straight scratching trees had increased in proportion to the other shapes. Presumably the animals scratched more frequently at straight trees because there were only a few inclined trees left. Very inclined scratching trees were scarce after thinning and their number did not increase in the following data collection. Therefore it could be shown that the animals preferred to scratch inclined trees but when such trees were no longer available they switched to straight trees.

However, thinning seemed to have a positive effect on the food supply for giant anteaters. Although I did not collect any data on this topic, I observed many new feeding signs of giant anteaters the day after thinning took place. Six weeks later the thinned area was covered with so many feeding signs that walking was problematic during the data collection. Thinning is reported to have positive effects on the biota within plantations, especially when cut trees are left within the plantation as done in my study area (Rishworth 1995, Lindenmaier & Hobbs 2004). However, the results of Kreutz in 2007 did not show a significant increase of anteater densities in thinned
areas. Further analysis should be conducted on the influence of thinning in *Acacia* plantations on giant anteaters.

2 Diet

In his study of dietary variation in giant anteaters, Redford showed that the animal responds opportunistically to local availabilities of prey (1986). Proportions of termites and ants in the diet varied from 100% termites in Northern Brazil to 100% ants in Paraguay. In all studies a marked preference for one of the two was found. A study in Venezuela reported differences in preferred prey items in different seasons with the diet consisting almost completely of *Camponotus* ants during the dry season and then increasing proportions of termites after heavy rain introduced the wet season (Montgomery & Lubin 1977).

My study revealed a relatively balanced proportion of 39% termites and 60% ants. Consistent with the study of Montgomery & Lubin (1977) the preferred ant genus was *Camponotus*. This was followed by *Dorymyrmex*. Ants of this genus have not yet been reported to be consumed by giant anteaters. *Dorymyrmex* species are known to establish colonies quickly and prefer highly disturbed areas (Farji-Brener et al 2002). This might be the reason why they occur in higher abundances within the plantation compared to natural habitats. The most preferred termite morphospecies was *Anoplotermes*, a species that does not have any soldiers and therefore presumably poor ability to defend the colonies (Baker & Walmsley 1982). The other consumed termite morphospecies belonged mainly to the subfamily Nasutitermitinae, a group that has, in contrast to Anoplotermes, very efficient defence (Montgomery & Lubin 1977, Baker & Walmsley 1982).

Nasutitermitinae soldiers have an elongated snout, the nasus, with which they squirt sticky secretions containing volatile terpenes at their enemies. Those secretions are supposed to taste bad or irritate the skin. An anteater that breaks open a nest of Nasutitermitinae will encounter a large number of nasute soldiers (Baker & Walmsley 1982). These termites are reported to be consumed, but giant anteaters feed remarkably shorter at nests of Nasutitermitinae (Redford 1985). Montgomery supposed that this is for avoiding nest defense, because soldier numbers typically increase with the time after a disturbance (Montgomery 1985). Because Redford (1985) showed, that Nasutitermitinae were only consumed despite
their defence when they appeared in high abundances, I assume that species of this subfamily are common within the plantation.

Small reptile eggs could be found in one of the feeding signs. They were partly destroyed and apparently consumed by giant anteaters. This can be ensured by the eggshells of the same size that were found in the faeces of the animals. My study is the first that reports reptile eggs to be consumed by giant anteaters. The giant anteater is commonly reported to be strict myrmecophagous in the wild (Redford, 1985). Only in one case an animal was observed to feed at beetle larvae (Krieg 1944).

Future studies should compare ant and termite compositions and densities between the plantations of *Acacia mangium*, the open savanna and riparian zones. Food supply is supposed to be an important factor in habitat preferences of giant anteaters though the animals seem to prefer the most available species in any given habitat (Redford 1986).

### 3 Habitat use

Home ranges of the observed giant anteaters, with the exception of GA6, included all available habitat types, namely plantations, savanna and riparian areas. The movement speed and direction of movement correlated with the attractiveness of a habitat: I could show that the animals moved fast and straight in the savanna, the habitat with the lowest selection index\(^5\), while they showed a significantly slower movement with many direction changes in the preferred habitats of plantations and riparian zones.

*Habitat preferences and food supply:* Montgomery and Lubin (1977) showed that the distribution and abundance of prey has an influence on the movement patterns of giant anteaters and I therefore assume that the different travel rates of anteaters observed in my study are caused by relatively higher prey availability in plantations and riparian areas than in the savanna. This is because high prey abundance leads to a rise in the frequency of feeding bouts and hence to a slower rate of travel. Kreutz showed in his study within the *Acacia* plantations in 2007 that the frequency of feeding bouts is much higher there than in the surrounding savanna or as reported from Redford 1985 or Shaw et al. 1985 for other parts of Brazil. He therefore

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\(^5\) Selection index: The quotient of time the anteater spent in a habitat and the relative habitat availability in its home range (page 46)
concluded that the density of prey is presumably very high and that the plantations provide an attractive habitat for giant anteaters due to the good food supply. High abundance of soil macrofauna in plantations of *Acacia* that were planted on savanna soils were reported in a study by Mboukou-Kimbatsa in southern Congo (1998). The Instituto Brasileiro de Administração Municipal (IBAM 2006) conducted an inventory in the *Acacia mangium* plantations of the Ouro Verde Ltda. focussing on the composition and abundance of the entomofauna. In their report they described a succession of the arthropods in the plantations that is correlated with the age of the trees and results in relatively low biodiversity but high abundances of hymenoptera, especially ants. The study comes to the assumption that, though the composition of the entomofauna is different from the savanna, the intensive presence of ants within the plantations presumably leads to the attraction of this habitat for giant anteaters.

After my observation, a better food supply could be actually one of the factors that make the plantations a preferred habitat. Giant anteaters moved across the savanna relatively fast and straight with the head held up high and only sniffing on single spots at the ground. In the plantations they showed a foraging behaviour similar to that which Redford in 1985 compared with the grazing of large herbivores: many ‘bites’ at many locations over a long period of time, the snout held mostly close to the ground. The anteaters showed similar behaviour when they were occasionally seen to forage in the riparian zone. Here the animals were also moving very slowly with many changes in direction and a high frequency of feeding bouts. In contrast to the plantation they did not dig in the ground for prey but lifted large fallen palm leaves with their claws and fed under them.

Summarizing the literature and my observations I assume that the plantations provide the best food supply for the anteaters, but that riparian zones are also used as foraging grounds. Intensely foraging animals could be observed exclusively in these closed habitats. The savanna only seemed to be crossed to reach riparian areas or remotely situated parts of the plantation. However, another main reason for
Part I Discussion

the avoidance of the savanna habitat could be as well a favourable climate within the plantation.

*Habitat preferences and weather conditions:* Another positive aspect for anteaters in the plantations might be the more stable climate of the forest habitat. Giant anteaters have a low metabolic rate and a low body temperature. Due to their long fur and the bushy tail that function as an effective insulation they have a wide range of thermo-neutrality (McNab 1984). However, depending on the season or the time of day, temperature can be a limiting factor for the giant anteaters’ activity. The animal is known to show variation in activity patterns and habitat preferences across its distribution. The animal is supposed to tend to nocturnal activity in regions with high daily temperatures and to diurnal activity when daily temperatures are moderate. Two of three studies about activity in giant anteaters described distinct periods of inactivity in giant anteaters. Montgomery and Lubin (1977) reported giant anteaters to be nocturnal and inactive throughout the day in the llanos in Venezuela. Average annual temperature in this study area is 27°C (Cruz and Andrews 1989). In the Pantanal wetland in Brazil with an average temperature of 25°C anteaters were inactive during the coolest and warmest hours of the day but showed no distinct diurnal or nocturnal activity pattern (Mourão & Medri 2007). The only study where giant anteaters showed no defined daily periods of inactivity was the study by Shaw (1985). Sleeping occurred irregularly. Shaw’s study was conducted in the Serra da Canastra National Park where the average annual temperature is 20°C (Medeiros & Fiedler 2003).

As well habitat use is influenced by weather conditions. Two studies determined habitat use in response to different ambient temperatures (Camilo-Alves & Mourão 2006, Mourão & Medri 2007). Anteaters were mainly active in open grasslands. Preferred resting habitats were forest patches especially on very hot or on cold days with chilly winds. It could be shown that forest patches in the Pantanal buffer the ambient temperature and provide shelter for the animals on days with extreme weather conditions. A comparable function of the plantations was already mentioned by Kreutzh in 2007.

At 28°C, the mean daily temperature during my study was the highest of all studies dealing with activity patterns of giant anteaters. Nevertheless, anteaters showed diurnal activity. Ambient temperature was correlated with activity, resulting in a lower activity around noon in the hottest hours of day. However, there were no times of total inactivity during daytime. Similar activity patterns have only been observed in
the Serra da Canastra where the average ambient temperature was eight degrees lower than in my study site (Shaw 1987).

I assume that the buffered forest habitat that the plantations provide allows the anteaters to escape to a certain extent from the restrictions of the ambient temperature.

**The meaning of natural habitat features:** With the highest selection index (page 46), the riparian zones represent an obviously important habitat feature for giant anteaters. Although it represented only a small part of the anteaters’ home ranges, the animals could be observed several times to visit these areas. Beyond providing foraging and resting habitat the most important function of riparian zones appears to be the water supply for the animals. In nearly all cases in which the animals were observed visiting the water sources, they drank from them. Giant anteaters are reported to satisfy their liquid needs by drinking the morning dew from leaves (Krieg, 1944). This observation could not be confirmed in my study. When visiting the water sources, the animals spent much time drinking, apparently taking in large amounts of water.

Bathing behaviour seems to be undertaken regularly by the coat care. In my direct observation of an anteater having a bath it did not start grooming directly as it reached the stream. It first lay down in the water with its eyes closed and rested for a short time. I therefore suggest that visiting water sources also appears to be connected with thermoregulation, which is as already mentioned, presumed to be a factor with a strong influence on the giant anteater’s behaviour.

The significant differences among individual anteaters in their frequency of visits to water source are difficult to explain and may be just individual preferences of the animals. About such aspects I can only make assumptions and further surveys about this topic should be conducted with radio telemetry.

Another function water sources appear to have is in connection with defecation. On one occasion an animal was observed to defecate in one of the drainage channels in my study-area. Shaw reported in 1985, that all defecations of giant anteaters in his study area occurred near or in water sources. He therefore assumed that surface water or related habitat conditions stimulate defecation. Exclusive defecation next to or inside water sources could not be noticed in my study. A high number of scats
were found within the plantations. I have no data about frequencies of scat in riparian zones and can therefore not compare faeces numbers in the different habitats.

The observation of the anteater drinking next to its dropped scat is consistent with data collected in the Dortmund Zoo. There, anteaters were frequently seen consuming water that contained faeces (see part two of my study). Drinking of water that contains faeces could be a form of auto-coprophagy - the consumption of its own faeces by an animal. To date coprophagy has not been reported for any myrmecophage animal. Auto-coprophagy is known mainly from rodents like rats, rabbits or capybaras that lack a complex ruminant digestive system and need to extract more nutrients by means of a second passage through their digestive tract (Taddayyon & Lutwak 1968, Borges et al. 1996, Hirakawa 2002). Important nutrients that are gained through auto-coprophagy include triglycerides, calcium, vitamin B, Magnesium and Phosphorus (Mameesh et al. 1959, Taddayyon & Lutwak 1968). There is no information about deficiencies resulting from a myrmecophage diet that might have to be compensated by the consumption of faeces and further studies would be interesting. If the defecation of faeces in the water by giant anteaters is connected with the uptake of nutrients, it might only occur when a deficiency exists. This would explain the observations of anteaters defecating in water sources as well as in the plantations.

In summary the water-sources in my study area seemed to be important landscape features for giant anteaters, used by the animals for drinking, coat care, defecation and possibly thermoregulation. Furthermore the surrounding riparian vegetation appears to be both an attractive foraging area as well as providing cover to rest in.

Water sources are also reported to play an important role for giant anteaters as a protection from wild fires. The animals can take refuge in riparian vegetation that functions as a natural barrier against fire (Silveira et al. 1999, Prada & Marinho-Filho 2004). In a study of the Emas National Park an intensive wild fire was extremely harmful to the anteaters’ population numbers (Silveira et al. 1999). Silveira presumed that anteaters are very susceptible to fire because of their slowness and inflammable fur. I additionally assume that the anteaters are capable of fleeing from fire over short distances, but that they are not able to run for longer distances due to their low metabolic rate. Hence, natural fire barriers such as riparian zones are extremely important for shelter and it can be suggested that the plantation areas provide protection in a similar way. The plantations are separated from the savanna by fire
breaks and there is always a troop of fire fighters prepared to defend the plantations from fires. Two giant anteaters were reported to flee from a wild fire that raged in the savanna straight across the fire break into the plantations. When they reached the trees they immediately sat down, breathing heavily, despite the close proximity of a number of fire-fighters. The animals seemed to be extremely exhausted and not able to flee further (pers. comm. Walter Vogel 2007). For animals that have high energy costs when traversing long distances at high speed as seems to be the case for giant anteaters, habitat heterogeneity provides not only shelter from fires but also allows more opportunities in reaction to other external factors (Lindenmayer & Hobbs 2004).

I consequently assume that the network of buritizais that crosses the savanna constitutes a key habitat feature, providing the anteaters with water and a shady, buffered climate as a shelter from extreme weather conditions. The considerable value of riparian zones for supporting biodiversity in plantations was stated by Lindenmayer and Hobbs in 2004. In my study area this importance of riparian zones for giant anteaters can be broadened to other species living in the savanna of Roraima, due to my observation of large numbers of animal signs and faeces along the riparian zone.

**Summary and implications for conservation efforts:** Several studies including my own, characterize the giant anteater as an animal with a strong capability to adapt itself to the local conditions of its environment. Over their geographic range the animals show remarkably different activity patterns, movement patterns and foraging behaviour including the chosen prey items.

Within their general distribution giant anteaters appear to be capable of living in habitats that provide four basic requirements:

1. Due to their limitation in energy expenditure because of the low calorific content of their prey they are restricted in their distribution to tropical habitats (McNab 1985 & 2000).
2. The abundance of prey (ants and termites) has to be high enough to provide them with a sufficient amount of food.
3. There have to be sources water in the area.
4. The landscape has to exhibit a certain degree of habitat heterogeneity, including areas with closed vegetation to provide shelter and a refuge from temperature extremes.

I assume further that besides direct threats from humans such as traffic or hunting, the quality and abundance of the last three points are the central factors that control the population density of giant anteaters. Considering these aspects, the strong decline of the anteater population in parts of the Brazilian Cerrado as a result of human activities (Miranda 2004, Klink & Machado 2005) can be explained as can the abundance of giant anteaters in the plantations of *Acacia mangium* (IBAM 2006, Kreutz 2007) where my study took place.

The Cerrado, a mosaic of savanna, forest patches and marshy lakes is a biodiversity hotspot. More than 50% of its previous extent has been transformed into pasture and agricultural land. As a consequence many species are threatened with extinction including the giant anteater (Klink & Machado 2005). One point with negative effects on the populations of giant anteaters and other animals in the Cerrado is the soil and ecosystem degradation due to agricultural practices and deforestation (Klink & Machado 2005). This gives rise to erosion and results in a reduced abundance and diversity of soil macrofauna, and therefore leads to a lesser abundance of prey for the giant anteater.

Agricultural practices also include the extensive use of fertilizers and lime (Müller 2003), which leads to the pollution of water sources like rivers and streams and this certainly poses a problem for animals that rely on clean water sources.

Furthermore, habitat heterogeneity is dramatically reduced by clear cutting and burning the savannas for pasture. Another direct threat to the anteaters is the seeding of invasive African grasses on the pastures. Silveira showed in 1999 that fires pose a bigger threat for giant anteaters when they are strong and last longer and the foreign grass species which can attain extremely high biomass result in more intensive fires.

Alltogether, the land use practices in the Cerrado affect the basic needs of the anteaters and have therefore led to a remarkable population decline.
Another picture can be observed in my study area in the state of Roraima, Brazil. The *Acacia* plantations of the Ouro Verde Ldta. adhere to the sustainable management guidelines of the FSC. They have been established without removing natural forest patches or buritizais. Therefore, water sources are still available and from the point of view of an anteater, the plantations increase the habitat heterogeneity, offering a new habitat with an optimal food supply. Giant anteaters appear to be the ‘winners’ within the plantations, because all their basic needs are optimally represented and because they are capable of adapting their activity, foraging patterns and social organization to the characteristics of the new habitat.

Lindenmayer and Hobbs specified a number of principles in their 2004 review about faunal conservation in plantation forest that have to be fulfilled by the plantation management to protect a maximum of the natural biota. The *Acacia* plantations of the Ouro Verde Ldta. meet all of them.

As the most important factor they listed landscape heterogeneity which can be achieved through spatial juxtaposition of stands of varying types and ages (in the plantations of the Ouro Verde Ldta. different stand qualities also contribute to heterogeneity). This principle relates to different elements of the biota having different requirements for resources that can be found in stands with varying quality or age.

Secondly they listed the importance of the size and shape of patches of remnant native vegetation within the plantations. Larger fragments can hold larger populations which are more stable and viable than small populations. The shape of native vegetation within the plantations has an influence on edge effects between plantation and remnant vegetation and have an influence on foraging efficiency for some animal species. After Lindenmayer, the borders of plantations to native vegetation should be as long as possible and a very packed adjustment of the plantations should be avoided. The third important point is the maintenance of riparian areas which have a degree of biodiversity disproportionate to the relatively small part of landscapes they occupy and which function as dispersal corridors for animals.

In these terms the sustainable management of the plantations of *Acacia mangium* meets the requirements for saving at least a part of the natural biota of the savannas of Roraima.
Nevertheless one should not forget that in this case natural savanna habitats are converted to forest. The lavrado is a unique ecosystem and its fauna is poorly studied and understood (Barbosa 2001). It is classified as an area of considerable interest for the conservation of the biodiversity of the Amazon biome (MMA 2008) and as one of the hotspots of endemism in South America (Barbosa 2007). A study in the savannas of Venezuela showed the extreme fragility of savanna ecosystems to human interventions, attributed to poor soils, slow growth of natural vegetation and erosion (Cabrera et al. 1998). The landscape needed more than 25 years to recover after slash and burn farming. The conversion of open savanna to forest habitat is a stronger intervention and the lavrado will probably never completely recover from this. Even though the anteaters as well as several arthropod species are apparently benefitting from the plantations, many other native savanna-species are surely not. The pressures on the lavrado increase, not only because of the growing extent of the timber plantations. The highest pressure comes from the development of the urban area of Boa Vista. Eighty percent of the people in Roraima live within 20% of the states area (Campos et al. 2008). The economy in the state has experienced a positive development with the per capita income rising from 2430 € in 2002 to 3240 € in 2005 (IBGE 2006). The economic development and improvements in infrastructure and the health system attracts increasing numbers of people to Boa Vista, the capital and biggest city of Roraima. The population of Boa Vista rose from 80.000 inhabitants in 1980 to 400.000 in 2008 (SEPLAN 2008). As a consequence land requirements and traffic increase and amplify the pressure on the native biota. Hunting and road kills will have a rising influence on population densities of giant anteaters as well as other animals.

Areas of conservation should be established as quickly as possible. Additionally more effective conservation of the riparian zones should be considered in the urban environment. The networks of brooks and rivers may carry the pollution that occurs in the city out into the open landscape. A chance for the natural environment of Roraima could be the rising interest in ecotourism for which the giant anteater is considered to be the flagship species (Barbosa 2007). The giant anteater is very

![Fig. 77: Road kill at the highway BR174, near to the city of Boa Vista in northern Brazil.](image)
popular amongst the local people (several pers. comm. with locals in Boa Vista 2008). Though there is no literature on this topic, many official home pages of Roraima and Boa Vista report an increase in the number of conservation projects dealing with giant anteaters due to the animal’s position as a symbol of the region (e.g. www.roraimaemfoco.com). The charisma of this species may save at least a part of the fauna and flora of the savannas of Roraima.

V CONCLUSION

For the successful assignment of the giant anteater as a flagship species and for the effective conservation of the species within the plantations, in the Boa Vista plain and in the rest of their distribution, many open questions have to be answered about the behaviour and the ecology of the animals. Further studies should be conducted in the *Acacia mangium* plantations in Boa Vista because of their unique position as a human created habitat with positive effects on the population of giant anteaters and due to the optimal conditions the plantations, with their high abundance of the animals, provide for behavioural observations. In my study I could only highlight parts of the spatial and social organization, movement patterns and habitat use of the animals in and around the plantations. A further study should be conducted by means of radio telemetry offering the possibility to determine detailed movement patterns over a long period of time. The results would allow an improved comparison with other studies. The social organization of the animals, habitat preferences and as well the home range size should be determined over different times of the year. In both studies that were conducted in the plantations (Kreutz 2007 and this study) the animals were observed at daytime during the summer months. Their behaviour should additionally be observed during the night and in the winter months. This would provide a more detailed understanding of the habitat requirements of the animals. The effects of plantation thinning on the animals needs further investigation as well as do other management procedures such as the use of fertilizers and harvesting techniques.
Part I Discussion

Though the plantation forestry in the savanna of Roraima surely has no positive overall effect on the native fauna, the existing positive effects on some faunal elements cannot be dismissed. Additional studies should be conducted to determine the influence of the plantations on other animal species. If further positive effects can be observed, this form of sustainable management could be adapted for other plantations in Brazil.

Brazil has an area of 2.7 million km$^2$ of deforested land. Recently it has been proposed to alleviate the pressure on natural forests by planting tree plantations for wood fuel, timber and pulp on these degraded landscapes (Ceccon & Miramontes in press). Though the conservation of natural habitats must always be the main focus, sustainably managed plantations could assist in the conservation of forest wildlife by providing complementary forest habitats, buffering edge effects and increasing connectivity (Brockerhoff et al. 2008). Those positive side effects could be of particular benefit to such scattered, fragmented habitats as the Atlantic forest (Ceccon & Miramontes in press). Tree plantations can play a further role in the future conservation of biodiversity. Exactly how and to what extent, still has to be determined.
PART II  Behaviour of giant anteaters in captivity

I  INTRODUCTION

Giant anteaters are popular animals in zoos all over the world. In 2003 the world zoo population summed up to 197 individuals, which breed successfully in captivity (Brandstätter and Schappert 2005). However, no studies are available on the behaviour of giant anteaters in zoos. I therefore conducted a pilot study in the Dortmund Zoo in Germany; a facility specialized in keeping giant anteaters.

The main aim of this study was to gain an overview on the behaviour of the animals in captivity and comparing it with my observations in the wild. Since I could not sex giant anteaters in my field study in Brazil, I wanted to determine in the zoo whether there is sex specific behaviour in giant anteaters. Ultimately the results of the zoo were combined with my observations in the field in order to develop a new concept of outdoor-enclosures for giant anteaters.

II  MATERIALS & METHODS

1  Study area

The Dortmund Zoo is specialized on the South-American fauna. It accommodates giant anteaters since 1975 and is the administrator of the European Stud Book for animals (Brandstätter & Schappert 2005). The zoo is the leading breeding facility for them with to date 55 births of giant anteaters. A particularity is the “South-America-Savanna” with a unique socialization of typical animals of the South American fauna including tapirs (Tapirus terrestris), capybaras (Hydrochoerus hydrochaeris), Chilean pudus (Pudu pudu) and giant anteaters. During my study period eleven giant anteaters were kept in several pens mostly separated, three females together in a group. The animals were housed in inside enclosures or stables during the night and left in the outside enclosures during the daytime when the temperature was above 17°C.

Enclosures for giant anteaters in the Dortmund Zoo:

1. South America enclosure (SA): A big meadow with a small quadratic pool where giant anteaters are kept with other South-American mammals such as capybaras (Hydrochoerus hydrochaeris) and lowland tapirs (Tapirus terrestris). The meadow
Part II  Methods

is very open with just some bushes and two trees. During my study period three females were kept together in this enclosure.

2. Eastern enclosure (EE): A T-shaped roofed pen, attached to an outside enclosure. One male giant anteater was kept solitarily in this enclosure.

3. Tamandua house (TH): A zoo building exclusively designed for keeping giant anteaters and other Xenarthra. Giant anteaters occupy three of the indoor enclosures observable for the visitors through glass panels. A male and two females (one in gestation and one with a cub) were kept separately and were alternately let out into the outdoor enclosure (WE) that is connected to the indoor pens.

4. Western-outdoor-enclosure (WE): Dense bushes are surrounding the Tamandua house, the remaining enclosure is a meadow modelled after the South American plains grassland. Since there are no trees in this enclosure, a 2.5m high trunk of a cut down tree was positioned on the meadow at the beginning of my study, as a scratching facility.

![Enclosures of giant anteaters in the Dortmund Zoo, Germany. SA = South-America-Savanna; EE = Eastern outdoor enclosure; TH = Tamandua House; WE = Western outdoor enclosure. Satellite-Image adapted from Google Earth, 2008.](image-url)
2 Study period
The study was conducted in September 2007, in the autumn with an average daily temperature of 17 °C. Temperatures ranged from 17 to 20°C on days when the giant anteaters were observed in outdoor enclosures. In the inside enclosures of the Tamandua house the temperature was relatively stable with more or less 20°C throughout the whole study period. Out of the 20 observation days, 9 were rainy, the rest unsettled with a mixture of clouds and sun.

3 Data collection
The giant anteaters in different enclosures were observed alternately at half an hour intervals. Scratching and sniffing frequencies were recorded, as well as water-interactions and defecation. The anteaters could be identified individually and therefore the sexes were known during all observations.

I manipulated scratching sides by rubbing straw with urine on it or gland secretion that was collected by rubbing the females’ urogenital tract with a piece of plastic. My aim was to achieve a subsequent comparison of the scratching frequencies at different manipulations, but the sample was too small to facilitate further analysis.

III RESULTS
1 Bathing behaviour in the Zoo of Dortmund
Anteaters had bathing opportunities in quadratic pools at the edge of the South America enclosure and at the western outdoor enclosure. Both spots were relatively open and positioned next to the visitors. In only two cases anteaters could be observed using those facilities: On one occasion the male (daytime: 8:39am; temperature: 18°C) and in the second case the mother with her cub (daytime: 4:00pm; temperature: 17°C) were using the pool in the western-enclosure for bathing and drinking (total observation time of this pen: 16 hours, mean temperature during observation period: 18°C). The anteaters entered the water and first sat down and groomed their fur. Then the mother with her cub swam a circle in the pool before leaving. The cub stayed on the mothers back during this activity.

Giant anteaters in the indoor-enclosures of the tamandua-house frequently spilled the water of their drinking bowls over the floor, subsequently sitting down in the water and grooming their fur.
2 Defecation behaviour

Giant anteaters were often seen defecating in their drinking bowls and drinking water that contained faeces. During my studies in the tamandua-house, feasible observations could only be conducted of the mother with her cup. The other female, which was in gestation, slept nearly the whole period of observation and the male was in the outside enclosure most of the time.

In a total of five hours of observation, the female was observed defecating two times in her water bowl (fig. 80). In one case she drank from the water after dropping faeces in it.

At the South-America-Savanna in the Dortmund Zoo, where cabybaras, tapirs and giant anteaters are kept together; a big water-trough was frequently used by both anteaters and cabybaras for defecation (fig. 81). Three female anteaters were kept together in this enclosure. I observed them for a total of ten hours. All three could be observed drinking very frequently from the water-faeces-mixture in the trough, although there were other drinking opportunities with fresh water.
3 Scratching behaviour in the Zoo of Dortmund

Sniffing and scratching in the upstanding as well as in the climbing posture could be observed frequently in the Dortmund Zoo. Males as well as females with- or without cub showed this behaviour. The female anteater in gestation was an exception showing none of those behaviours but rather sleeping for almost the entire study period with only short breaks for food and water intake or for defacation.

Several objects within the enclosures were used for sniffing or scratching:

1. South America enclosure: The three female anteaters kept in this enclosure sniffed and scratched frequently in the upstanding posture at the gate to their enclosure. The gate showed brown sediments of gland secretion or dirt at the spot where the animals rubbed their chest during scratching. Additionally, they interacted with a tree, displaying the upstanding posture without scratching, because the tree was encased with a funicular fence. Frequently two anteaters were in the upstanding posture at the tree at the same time.

2. Eastern enclosure: The male in this enclosure sniffed and scratched as well in upstanding- as in climbing posture at a gate. Thick, brown sediments of presumably gland secretions could be found here.
3. **Tamandua house**: All pens in the Tamandua house offered big tree trunks as scratching opportunities. Only one anteater (the female with her cub) was observed for a time adequate to be included in the analysis. The anteater used the trunk as well as several jutties for scratching and sniffing.

4. **Western enclosure**: In this enclosure no spot for sniffing or marking was used by the anteaters in the beginning of my study. Zoo-keepers reported that there used to be a big tree which was used frequently for scratching and sniffing by the animals. It had to be removed one year before my study (pers. comm. Ilona Offhaus). In the second week of my examination a big tree trunk was put in the pen for scratching.

**IV DISCUSSION**

No distinct differences in female or male behaviour could be observed. However, males are reported to have a lower intra-sexual acceptance and cannot be kept together in one pen (pers. comm. Ilona Schappert). In contrast, the three females that were kept together at the South-American enclosure showed a very close association. Since the animals spent clearly more than 50% of the time together in one corner of the enclosure and interacted with each other frequently this can be defined as sociality (Wiens & Zitzmann 2003). One daily interaction was approximately half an hour of playing. The anteaters performed ‘game-fights’, pushing each other or pressing the other one on the ground without using their claws (fig. 83). Frequently the animals ran to the trees in the enclosure while playing and displayed the upstanding posture, apparently as a displacement activity out of pure excitement. Sometimes two females interrupted their play, ran to one of the trees and both stood up at it at the same time (fig. 85). Another kind of interaction that two anteaters displayed frequently was licking each other in the mouth (fig. 84) or licking each others ear.

Consequently it can be supposed that for female giant anteaters in the wild, spatial avoidance does not seem to result from a basic aversion to conspecifics, but appears to be of benefit due to the distribution of limited resources in the wild. The avoidance among males presumably has other reasons. More studies need to be conducted to clarify which are the essential resources that trigger the social organization of giant anteaters.
Scratching was displayed in the upstanding posture by all giant anteaters, even by females that carried a cub on the back. An exception was the one in gestation which was physically limited due to her weight. The climbing posture was only displayed by one of the males, presumably because the enclosures of the other animals were lacking structures for climbing. There were popular spots in the enclosure that were scratched regularly and showed conspicuous scratching marks as well as brown sediments which I presume to be gland secretion. There is no literature that describes explicitly that giant anteaters have skin- or urogenital gland secretions, but I could personally observe glands at the ventral side of the body which release a red/brown secretion (fig. 82). Additionally, the females excreted a brown secretion at their urogenital tract. This could not be checked for males, because the handling of them is more precarious. Three times I presented the piece of plastic that carried the gland secretion I collected from the female in gestation to the three other females at the South-American enclosure. In all cases the anteaters began to play immediately with each other after sniffing at the secretion. This indicates that the secretions are of social relevance, a point that should be determined in further studies.

Giant anteaters are usually characterized as a savanna–species (Eisenberg & Redford 1999). Therefore most outdoor-enclosures of giant anteaters in zoos are designed as “savannas”, generally composed of grassland and bushes. I suppose that the belief that these animals are associated with open vegetation emerges from the fact that there are so far no studies on giant anteaters in forest habitats. Presumably this is because it is problematic to locate them in this environment, amongst other reasons, due to their optimal camouflage.

All studies on habitat use of the animals in grasslands and savannas reported giant anteaters using available forest habitats to a certain extent, especially for resting and thermoregulation (Shaw et al. 1987, Medri 2005, Camilo-Alves 2006, Mourão & Medri 2007). In my fieldwork in timber plantations in Brazil, closed vegetation was clearly preferred and savanna was even avoided. The closed vegetation offered apparently better food supply and a stable climate for the animals. Additionally Kreutz supposed...
Fig. 83: Giant anteaters playing with each other in the Dortmund Zoo, Germany.

Fig. 84: A group of three female giant anteaters in close social interaction in the Dortmund Zoo, Germany. Two are licking each other in the mouth with their long tongue while the other one licks the fur of a conspecific.
Fig. 85: Female giant anteaters displaying the upstanding posture at a gate and a tree in the South-America outdoor enclosure in Dortmund, Germany.

Fig. 86: Male giant anteater climbing its gate in the eastern enclosure at the Dortmund Zoo, Germany.

Fig. 87: Female with a cub on her back displaying the upstanding posture.
in 2007 that the plantations also provide shelter to the animals. Animals in the savanna that were disturbed immediately ran back into the plantations. All studies on habitat use of the animals in grasslands and savannas reported giant anteaters using available forest habitats to a certain extent, especially for resting and thermoregulation (Shaw et al. 1987, Medri 2005, Camilo-Alves 2006, Mourão & Medri 2007). In my fieldwork in timber plantations in Brazil, closed vegetation was clearly preferred and savanna was even avoided. The closed vegetation offered apparently better food supply and a stable climate for the animals. Additionally Kreutz supposed in 2007 that the plantations also provide shelter to the animals. Animals in the savanna that were disturbed immediately ran back into the plantations.

In the zoo I equally observed, that the animals preferred the denser vegetation. Enclosures of giant anteaters in zoos I visited (e.g. Dortmund Zoo, Germany and Tiergarten Schönbrunn, Vienna, Austria), were all structured with bushes, situated at the outer edge of the enclosure surrounding an open meadow. The anteaters remained mostly within the bushes, being invisible to the visitors.

As the largest existing Xenarthran with an endemic Neotropical distribution the giant anteater is a charismatic ambassador for the South-American fauna and an attractive zoo animal. With some changes, the enclosures would be more suitable when keeping these animals in zoos and, at the same time their presentation would be more attractive to the visitors.

Based on my extensive fieldwork and observations in captivity, I recommend the following changes in enclosure design for giant anteaters.

First I want to recommend designing the enclosures as an open forest habitat, with trees planted intermittently. The trees create a more stable climate and provide the giant anteater with shelter from cold or very hot weather. Additionally, my opinion is that the animals generally feel safer under closed vegetation and therefore will presumably use the whole enclosure instead of only the outskirts. In contrast to bushes, trees do not restrict the visitors' view on the animals.

As shown in my study, the animals do not scratch dead trees, which might be the reason why the established trunk in the Western enclosure was not used for scratching. Instead there are many reports and photos to be found in the internet of giant anteaters in zoos scratching trees that are alive, showing the upstanding and climbing posture. I presume that the animal would display this behaviour frequently when kept in an enclosure with trees.
However, some insulated bushes should be planted as sleeping sites and as refuges.

Since much of the giant anteaters’ interesting behaviour is connected to riparian zones in the wild and water also has a distinct attraction for anteaters in captivity for swimming and grooming, there should be a focus on variable water structures in the enclosure. As an optimal combination, I consider a shallow brook or pond for grooming and resting, and additionally a deeper pool for swimming.

As in the Dortmund Zoo, keeping several anteaters together in one enclosure had a very positive effect on the animals’ activity, with an extremely entertaining behaviour when the anteaters are interacting with each other. The co-housing with capybaras and tapirs also functioned very well. The anteaters were frequently seen licking tapirs’ or capybaras’ ears and the other animal seemed not to reject this at all. Therefore I recommend co-housing with conspecifics or other species if possible.

Several other ideas exist to present the animals in an attractive way. In London for example, the animals go for a walk in the zoo once a day. A possibility should be developed to present the unique feeding behaviour and -morphology of the giant anteater to the visitors. I could imagine a feeding opportunity with a box (that could be designed as an artificial termite mound) with only small openings, so that the animal has to use its tongue to reach the food items. Meanwhile the feeding activity can be observed by the visitors through a glass panel in the box on the visitors’ side.

V CONCLUSION

The social interactions in the zoo among female giant anteaters were extremely different to the observed behaviour in the wild. Further studies should determine the factors that lead to this difference. Zoos that plan to establish giant anteaters in the future should consider a different enclosure structure. Giant anteaters are such charismatic and fascinating animals; an adequate presentation of them in the zoo could give them the position as an international ambassador and flagship species for the nature of South America and especially for the endemic Xenrathra, this unique and charismatic group of animals that characterize the fauna of the Neotropics.
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…because anteaters can do everything, if they had wings they could even fly.
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References


Glossary

GLOSSARY

- **A. auriculiformis** – Species of trees that grows accidentally in the plantation and is economically of little value.

- **ADK** – Adaptive Kernel Density: Method of home range estimation, respecting the utilisation distribution density.

- **A. mangium** – Tree species that is planted in the plantations for wood and cellulose production.

- **GLM** – Generalized Linear Model: A flexible generalization of ordinary least squares regression

- **FSC** – Forest Stewardship Council: international non-profit organization which promotes responsible management of the world’s forests

- **Lavrado** – An open savanna formation dominated by the herbaceous stratum (herbs and grasses).

- **MCP** – Minimum Convex Polygon: Method of home range estimation.

- **Talhão / Talhões** – Small management units within the plantation with a size of 10 – 40 ha, surrounded by roads.

- **Thinning** – A management procedure where all dead and not promising trees as well as all A. auriculiformis are cut down to increase wood production
This study represents original work by the author and has not been previously submitted in any form for any degree or diploma thesis to any University. Where use has been made of the work of others it is duly acknowledged in the text.

Lydia Möcklinghoff

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