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DeBrazza's Monkeys (Cercopithecus neglectus) in a Mixed-Taxa Zoo Exhibit: Effects on the Behavior of a Breeding Group of DeBrazza's Monkeys After the Birth of an Infant

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Abstract

Historically, zoos rarely feature mixed taxa exhibits including multiple primate species; the Minnesota Zoo opened such a unique four-species exhibit featuring Rock hyraxes, Red River hogs, Colobus monkeys, and DeBrazza's monkeys in May, 2010. Because of potential problems associated with territoriality and aggression, primates in mixed-taxa exhibits are generally non-breeding. However, the DeBrazza's monkeys at the MN Zoo are a breeding pair with a juvenile offspring. The intent of this study was to design an ethogram with the purpose of calculating the effects of a mixed taxa exhibit on the behavior of this breeding group, and to compare their behavior before and after the birth of an infant. Pre-birth behavioral observations established activity budgets for the DeBrazza's with the adult male spending 71% of his time resting and 14% of his time in food related activities. The adult female spent 85% of her time resting and only 4% in food related activities, and the juvenile spent 25% of her time resting and 35% of her time in food related activities. Post birth, the adult male spent 68% of his time resting, and 16% of his time with food, the adult female spent 85% of her time carrying the infant, and the juvenile spent 34% of her time resting and 28% of her time with food. Each animal also spent different amounts of time near the other animals. Significant differences in amount of time that the adult female and the juvenile spent near each other were found, as well as differences in the amount of time the adult male spent near the Colobus. These differences and the animals' activity budgets illustrate how these species interact in this zoo exhibit as well as identify areas for future research with these populations.

DeBrazza's monkeys (*Cercopithecus neglectus*) in a mixed-taxa zoo exhibit: Effects on the behavior of a breeding group of DeBrazza's monkeys after the birth of an infant

When faced with the task of designing a project to study a group of primates in a unique mixed-taxa zoo exhibit, many factors must be taken into consideration. The specific traits of the species that is being studied need to be accounted for, as well as the effects of captivity and inter-specific interactions (because the exhibit includes four species in one enclosure). Additionally, the reproductive state of the reproductively active group of primates should not be ignored. In order to make comparisons across time, the methods used to record the behaviors should be detailed enough to account for changes within the group (such as the birth of an infant), or just changes across time. The purpose of this project was to design a methodology to observe a group of DeBrazza's monkeys in a mixed-taxa exhibit at the Minnesota Zoo in order to make comparisons before and after the birth of an infant, or across changes in other variables such as an addition of an enrichment item. The project explored the process of designing an effective ethogram and behavior sampling protocols for a zoo exhibit of primates within the context of observing the behavior of the group before and after the birth of an infant. In this paper I first give background information on the study species and parenting in primates in general. I then describe zoo research and the exhibit in which the study took place. I finally describe observational behavior research, and its importance when studying animal behavior. I also discuss my methodology and some of the behaviors and patterns I observed over the course of the project such as changes in activity budgets and

changes in the individuals with whom each monkey spent time in proximity, as well as their possible implications for future research and protocol design.

DeBrazza's Monkeys

DeBrazza's monkeys (*Cercopithecus neglectus)* are a species of Old World monkeys that is widely distributed across east and central Africa. They can be found in Ethiopia, the basin of the Congo River, and in parts of Uganda and Kenya (Brennan, 1985; Oswald & Lockard, 1980; Mwenja, 2007; Wolfheim, 1983). DeBrazza's belong to the family Cercopithecidae (which includes all Old World monkeys) and the subfamily Cercopithecinae, which also includes mangabeys, papas, macaques, mandrills and baboons (Fleagle, 1988; Montagna, 1976). These monkeys are differentiated by the presence of cheek pouches, which are absent from the other subfamily Colobinae. They also differ widely in their diets; the colobines eat mainly leaves and seeds and the cercopithecids eat more fruits. Colobines have a complex stomach, that cercopithenes do not, that evolved to aid in digestion of their high fiber diet, and although these two subfamilies are often found in similar environments, they do not often compete with each other for food resources because they are specialized to eat different things. This is relevant for zoos as well because these monkeys tolerate each other in the wild, so they should tolerate each other in captivity. In Africa, most DeBrazza's have been found living along rivers; they are rarely found in non-riverine habitats (Mugambi, Butynski, Suleman, &Ottichilo, 1997; Wahome, Rowell, & Tsingalia, 1993). Wahome et al. (1993) observed that DeBrazza's (in Kenya) spent more time in the swampy parts of their habitats, even though the swamp represented a relatively small part of their total home

range. Typical home range for these monkeys is about 5 hectares (Wahome et al., 1993; Wolfheim, 1983). DeBrazza's generally are low-dwelling arboreal monkeys, spending relatively little time high in the canopy, and can move along the ground successfully (Manaster, 1979). In Kenya, DeBrazza's were observed moving a little more than 300 m per day (less during the dry season). They also moved up and down within the canopy depending on time of day and location of food (Wahome et al., 1993). These observations about characteristic DeBrazza's preferences in the wild can have important implications for the design of an effective captive enclosure, such as including water because of their riverine preferences and branches that are at a preferred height for the monkeys.

DeBrazza's monkeys are omnivorous, and their diet consists of leaves and berries, fruits, flowers, and some invertebrates (Wahome et al., 1993). In the wild DeBrazza's have been observed to feed on one or two fruit trees until most of the fruit was consumed. They also feed regularly on herbs and climbers. When consuming invertebrates, DeBrazza's were meticulous in their method of capture, often carefully uncurling the leaves in which the invertebrates were living and using their hands when eating (Wahome et al., 1993).

DeBrazza's monkeys are unique within the guenons (genus *Cercopithecus*) whose forest dwelling members include *C. cephus, C. pagonias, C. nictitans,* and *C. talopolin* as well as *C. neglectus*. DeBrazza's are more frugivorous than the other guenons, and they move more slowly than some of the other smaller guenon species. They live in much smaller groups, and they have marked sexual dimorphism (Fleagle, 1988). They have

been observed in monogamous groups (as cited in Fleagle, 1988; Leutengger & Lubach, 1987; Wahome et al., 1993), which is particularly challenging because historically sexual dimorphism is found in polygynous (not monogamous) organisms. They even have greater body weight dimorphism than many polygynous species, an unexpected feature in an animal that has been observed in a monogamous pair. Because DeBrazza's display these features commonly associated with polygyny, they continue to be described as a polygynous species even though many populations have been observed to be monogamous (Leutengger & Lubach, 1987). Groups have been observed containing anywhere from one to ten individuals. Some groups in the wild were observed to have one adult male, one adult female and one or two juveniles. Other groups had one adult male and two adult females and offspring (Estes, 1991; Leutengger & Lubach, 1987; Mugambi et al., 1997; Wahome et al., 1993). Many of these differences may be related to different social systems in different populations, which could be associated with food resource availability. Both the monogamous groups and the polygynous groups seem to maintain a high level of stability, suggesting both strategies are effective for this species.

Female DeBrazza's monkeys reach sexual maturity and mature body weight of about 4 kg at around 4 years of age, and males reach sexual maturity and mature body weight of around 7 kg at about 6 years of age (Leutengger & Lubach, 1987; Wahome et al., 1993). When a male reaches sexual maturity his behavior changes, with an increase in displays, a decrease in certain calls, and increase in other calls that announce that a male is ready to perform his role of group defense and leadership (Leutengger & Lubach, 1987). Mature males have been observed living alone before forming their own group

(Mugambi et al., 1997). A female's achievement of sexual maturity is marked by pregnancy. Gestation for DeBrazza's monkeys is 5.5-6 months, and the typical interval between births (for one female) is 20 months. DeBrazza's females in captivity have been known to continue to breed into their late teens (Rowell & Richards, 1979). These species typical behaviors and environmental preferences influenced the design and protocols of this project that seeks to study a breeding group of DeBrazza's monkeys at the Minnesota Zoo in Apple Valley, MN.

Parenting in Primates

Parenting takes many forms across the animal kingdom. Some invertebrates lay eggs and leave them to hatch and mature on their own, while some birds care for their newly hatched offspring, but this care lasts for only a few weeks to a few months. Primates display a wide variety of parenting strategies, but all strategies involve relatively high levels of investment. Primate infants are particularly altricial (undeveloped and requiring parental care) at birth, so parenting in primates is important for the survival of offspring (Clutton-Brock, 1991; Smith, 2005). Gestation, birth, and caregiving are energetically costly behaviors. The mother pays most of these costs, and in most primate groups, parenting behaviors are only exhibited by females (Baker, Baker, & Thompson, 1996; Box, 1984; Clutton-Brock, 1991; Fairbanks, 1993; Fairbanks, 2003; Hutchins, Thomas, & Asa, 1996; Rosenblum & Sunderland, 1982).

However, that is not to say that other members of the group ignore the new infant. Many studies have been done that explore the role of alloparenting (parenting done by individuals other than the mother) in primate groups (Baker et al., 1996; Box, 1984;

Clutton-Brock, 1991; Hutchins et al., 1996; Smith, 2005). Most instances of allomaternal behaviors have been observed in juvenile or adult females within a larger social group of primates (Fairbanks, 1993; Hutchins et al., 1996). Alloparental care includes behaviors such as grooming the infant, watching the infant, or more obviously caring for the infant (such as nursing or carrying an infant other than one's own). Scientists have observed differences in the ways in which different species alloparent (or more specifically how much alloparenting is tolerated by the mothers) (Fairbanks, 1993). It is in the best interest of the mothers both to minimize the amount of time spent carrying and caring for their offspring and minimize the amount of time the infant spends alone. The theory is that each mother is working towards to maximizing her own reproductive fitness, which requires a balance of care for current offspring while making sure to maintain enough resources to care for her next infant (Fairbanks, 1993). Cercopithecine species (the group to which DeBrazza's belong) are less tolerant of alloparenting than colobine species. Cercopithecine mothers might tolerate attention shown to their infants, but they do not often allow other females to pick up their infant and carry it around (even though this might lessen their energetic costs of raising the infant); (Box, 1984; Smith, 2005). Still, Bryne, Conning, and Young (1983), did observe alloparenting by most members of a group of Diana monkeys (*Cercopithecus diana*), a closely- related species to DeBrazza's. Additionally, Forster and Cords (2005) observed significant amounts of alloparenting by older juveniles in a group of blue monkeys (*Cercopithecus mitis stuhlmanni*). They also found juvenile females performed much of the alloparenting (rather than juvenile males), and that there were significant individual differences in the amount of alloparenting each

mother allowed and the amount that each juvenile attempted (Forster & Cords, 2005). Although it takes different forms, mothers do often rely on their social group when raising offspring. Grandmothers, especially, have been shown to aid with care of their daughters' offspring (Fairbanks, 1993). Laboratory studies showed that rhesus macaque mothers that were separated (with their infant) from their social group were more likely to abandon or reject their offspring than the mothers that were allowed to stay with their group (Harlow, Harlow, & Hansen, 1963; Smith, 2005). This shows that alloparenting probably plays an important role in reducing the costs of raising offspring, and mothers faced with the prospect of raising their young without the support of an extensive social system might find the costs to be too high.

Attachment has also been shown to play a role in maternal care in non-human primates (Smith, 2005; Waters & Deane, 1982; Wiesenfeld & Malatesta, 1982). Just as in human mother-infant interactions, mother non-human primates cuddle and play with their offspring. They also display behaviors that can be interpreted as trying to keep their infant dependent while the infant tries to be more independent (Harlow et al., 1963; Smith, 2005). Mothers have also been shown to have physiological reactions to infants' distress calls (Wiesenfeld & Malatesta, 1982). Different mothering styles have been associated with different social grouping patterns and different levels of experience. In a multi-female group with dominance hierarchies lower-ranking mothers may interact with their offspring differently (i.e. more protectively) than higher-ranking mothers (although in my monogamous study group dominance is not a factor because there is only one adult female DeBrazza's monkey). Additionally, first-time mothers seem to be more

protective of their infant than more experienced mothers, although protectiveness increases in experienced mothers if their previous infant died (Fairbanks, 1993; Smith, 2005). Different patterns are also displayed depending on food availability. While this is not an issue when studying captive populations, food distribution and abundance have been shown to play a crucial role in determining mother-offspring interactions and care in wild primates with more care and energy in parenting associated with higher levels of food abundance (Rosenblum & Sunderland, 1982). However, there are general patterns of maternal care based on infant development displayed by many primate species. Primate mothers maintain high levels of contact with their infants for the first few months after birth. As the infant gets older, the mother works less hard at maintaining contact, and increasing amounts of contact are initiated by the infant. Finally, when the infant is about six months old, the mother enters her first estrous cycle since the birth of her most recent infant, after which she much more forcibly rejects her infant as it approaches (Fairbanks, 2003). Although this is not a hard and fast rule for maternal behavior, this pattern is one that works towards maximizing the mother's fitness. The birth of a new infant has also been correlated to changes in how the mother and previous offspring interact. In many species, the next infant is born when the juvenile is around a year old. The mother then becomes much more aggressive towards the juvenile and spends most of her time and energy caring for her current infant. The juvenile reacts to this by increasing its independence and interacting more often with other group members (Fairbanks, 2003). Furthermore, studies have shown a correlation between the amount of time spent in contact with one's mother with the amount of time spent in contact with

one's own offspring, although this is not necessarily an indication of reproductive success (Smith, 2005). Some of the mother-infant contact occurs because many non-human primate mothers carry their infants ventrally thus giving the infants access to nurse almost twenty-four hours a day. Access to nursing is important for primate infants to grow and develop appropriately (Rosenblum & Sunderland, 1982; Smith, 2005).

Males show varying amounts of paternal care for offspring depending on species as well as other environmental factors (Baker et al., 1996; Lamb & Goldberg, 1982; Smith, 2005). Males in captivity might behave differently towards offspring than males observed in the field, and this might be related to increased certainty of paternity in captivity. A primate male (especially in the wild) is rarely sure whether he is the father of an infant, so it is an evolutionary strategy to expend as little energy as possible raising offspring that might not be genetically related (Baker et al., 1996; Smith, 2005). More paternal care is observed in species where the male can be surer of his paternity, i.e. in monogamous species. Males in monogamous pairs have a lot to gain by helping to care for their offspring, so in order to maximize their fitness, they aid in parental care. This seems to be an evolutionary strategy that has evolved most often in monogamous species, but not all males in monogamous groups alloparent (Baker et al., 1996; Box, 2005). Differences in paternal care have also been observed based on the context in which the male finds itself with the infants. Sometimes males might interact with infants if the mothers are removed (in a captive setting), showing that males are capable of parenting behaviors even if they save their energy and let the mothers take care of the offspring most of the time. The most common form that paternal care takes is protection. Adult

males defend territories, and this often also protects infants from infanticide or predators (Baker, et al., 1996; Box, 1984; Smith, 2005). Because DeBrazza's are found in both polygynous and monogamous social groups, one would not necessarily expect that the males have evolved a strategy to help care for offspring. Because this study explores how individuals interact with the infant as well as how their behavior changes after the infant is born, understanding parental care in primates is an important aspect of this project.

The Zoo Exhibit

Historically, zoos have often housed different species together because in many cases it saves space. However, most of those exhibits did not involve mammals. It is only recently, and with a lot of care and consideration, that zoos have begun to house mammals (especially primates) together (Hosey et al., 2009; Thomas & Maruska, 1996). According to the Old World Monkey Taxon Advisory Group Mixed Species Manual (Association of Zoos and Aquariums, 2007) some considerations have to be taken when putting primates into mixed taxa exhibits. They recommend that there be space in the exhibit for each species to occupy, and they recommend that the species be separated at night or be given an option to separate themselves. They also state that solitary and geriatric animals make the best "cage mates." Colobus monkeys are also encouraged because they are arboreal, and occupy space that is very different than other terrestrial or lower arboreal animals (AZA, 2007). The Diana monkey is a closely related species to the DeBrazza's monkey, and a group of them has successfully been housed with a group of gorillas at the Edinburgh zoo (Young, 1998). Additionally, Wojclechowki (2004)

described a successful introduction of a group of red-capped mangabeys (*Cercocebus torquantus*) into an exhibit that already housed three other primate species. However, none of the primate groups studied were breeding (Wojclechowski, 2004).

The exhibit at the Minnesota Zoo features four groups of animals that all can be found in the jungles of Africa. The exhibit has Rock Hyrax which are large African rodents (*Procavia capensis*), Red River hogs (*Potamochoerus porcus*), Black and White Colobus monkeys (*Colobus guereza*), and DeBrazza's monkeys (*Cercopithecus neglectus*). There are at least five Rock Hyrax (they are breeding), a pair of Red River Hogs, three Colobus monkeys consisting of two males who are brothers born in 2004 and 2005 and one female Colobus monkey (born in 1998) who is non-reproductive, and four DeBrazza's monkeys consisting of one male (born in 2001), one female (born in 2000), their one-year old offspring (born July 29, 2009), and as of December 10, 2010 their newest infant (whose birth was unexpected, yet presented a unique opportunity to observe how these groups interacted directly after its addition to the exhibit). It is important to house animals together in groups in which they might be found in the wild because this has been shown to reduce stress in captive populations, and these species all live in similar habitats in Africa (Hosey, Melfi, & Pankhurst, 2009). Because DeBrazza's have been observed in monogamous groups in the wild, this social grouping is appropriate for these animals.

At the Minnesota Zoo, the Faces of Africa exhibit is the first of its kind. Although these animals do all live together in the wild, they have never been in this exact situation in a zoo exhibit ever before. Usually it is considered safer if none of the primate

groups are breeding if they are going to live in a mixed taxa exhibit. In fact, the other one other zoo that attempted to put breeding DeBrazza's in with Colobus eventually decided that they needed to separate the two species and only have one on exhibit at a time because there were too many aggressive interactions between the groups (and Red River hogs, a species that might also have aggressive interactions with the primate groups, were not even part of the equation) (AZA, 2007). Still, at the Minnesota Zoo the group of DeBrazza's is reproductively active and living with another non-breeding group of primates as well as Red River hogs and Rock Hyraxes.

The exhibit at the Minnesota Zoo has many integrated features designed for the health of the animals inside, as well as to provide space for each of the four taxa living there. Research into the important aspects of zoo exhibits for primates has shown that vertical space and consideration for group dynamics are important when designing zoo enclosures (Hosey et al., 2009; Maple, 2007). The Minnesota Zoo took these findings into consideration when designing this exhibit. There are branches and tree trunks for the monkeys (with separate branches intended for each species, based on their behavior patterns in the wild). There is a waterfall, which provides enrichment, and mimics the DeBrazza's natural proclivities for riparian habitats. There are mulch pits in which the hogs can dig, and rocks with ledges on which the hyrax can rest. The concrete trees and branches are designed to give a little which mimics real tree branches, and there are branches on which the monkeys can swing.

In the wild, DeBrazza's avoid interspecific interactions. They are overtly aggressive when they encounter other monkeys. The clear exception to this rule is

Colobus monkeys (Mugambi et al., 1997; Wahome et al., 1993). Scientists believe that the DeBrazza's monkeys tolerate Colobus because their respective digestive systems are so different they do not actively compete with each other for food. The Colobus eat a much higher proportion of leaves than do the DeBrazza's (Wahome et al., 1993). This is why it is acceptable to house these two species together in captivity.

With regards to enrichment, the animals have a very complex habitat in which they live. They can utilize the many branches as well as climb on the rocks on the sides of the enclosure. The keepers also often provide browse and other natural enrichment on exhibit for the animals to manipulate and eat. The keepers regularly spray perfume in the enclosure to give the animals unique smells to investigate. There is also an extensive list of enrichment items that have been determined acceptable for these animals. Sometimes these objects are unique food items such as peanut butter, and during holidays such as Halloween, pumpkins are occasionally provided as novel objects that the animals can manipulate. Most often the keepers hide food items within the exhibit in order to encourage foraging behaviors. Off exhibit the primates are frequently provided with toys; many of which were designed for human infants and some that require manipulation in order to get a small food treat.

Each of the primates also has a training plan that allows the animals to learn behaviors important for husbandry. Training allows keepers to effectively move animals on and off exhibit as well as making the process as relaxing as possible for the monkeys. The Colobus get trained on exhibit at a specially designed tree that allows one animal to approach the keeper at a time while the DeBrazza's are most often trained off exhibit in

the mornings and evenings. This minimizes the competition for keeper attention and decreases incidences of aggression. Originally each animal was trained to follow a target, and the primates have also learned to present their hands and arms for blood draws. The target training allowed the keepers to train the monkeys to separate themselves in order to get trained one at a time, and training behaviors that are related to veterinary care allow the monkeys to remain calm when being inspected by a vet.

Behavioral Observation

When observing behavior it is important to establish a set of protocols in order to define what behaviors you are looking for, and determine exactly how behaviors are going to be recorded. An ethogram is a useful tool for the behavioral scientist (Huntingford, 1984; Lehner, 1979; Martin & Bateson, 1986). An ethogram is a "catalogue of descriptions of the discrete, species typical behavior patterns that form the basic behavioral repertoire of the species," (Martin & Bateson, 1986). The ethogram provides specific behavioral definitions yet is comprehensive enough to describe almost any behavior that is observed. Often ethograms are based on the state the animal is in at a particular time, such as 'resting,' which may be further defined as 'eyes open or closed.' Using an ethogram allows behavioral observations to be quantified. Before ethograms are established many qualitative observations of the species being studied are made in order to ensure that important behaviors are not excluded from the ethogram (Altmann, 1974; Crockett, 1996; Lehner, 1979; Martin & Bateson, 1986). It is also important when designing the ethogram that the behavioral categories are mutually exclusive and that protocols be established for determining which behavior category

takes precedence over others. When this is not firmly established it becomes difficult to compare across categories and quantify relative amounts of time spent in each behavioral state (Crockett, 1996).

Ethograms can be utilized to answer specific questions about behavior, but they are also useful for establishing activity budgets for the animals being observed. An activity budget is a description of how the animal is spending its time based on observed behaviors. This is important for a number of different situations. In the wild, activity budgets can be used to determine how a particular organism spends its day and interacts with its environment. In captive populations, activity budgets can be used for effective enrichment management (Crockett, 1996; Mallapur, 2005). Consider: an animal is observed spending too much time repeating one behavior that prior activity budgets of healthy animals (perhaps in the wild) did not observe often; from this, actions can then be taken to determine the causes of the inappropriate behavior. Activity budgets are also useful if one wants to determine the effects of a new enrichment protocol or a change to an exhibit. Comparisons of behaviors observed before and after an introduction of a new enrichment item could be used to correlate a change in behavior to the enrichment item. Similarly, the birth of an infant can have numerous effects on the behavior of each member of the group. Although much zoo research is interested in correlating changes in behavior to changes in environment or enrichment, in a captive setting it is often difficult to manipulate variables, so much of the work that is done in zoos is descriptive in nature (Crockett, 1996).

Because of the unique nature of the Minnesota Zoo exhibit, the ethogram and observation protocols were designed not only to establish an activity budget for the primates being observed, but also to focus on social behaviors and interspecific interactions, which may be influenced by the mixed-taxa group dynamics. It was also in-depth enough to measure changes in behavior before and after the birth of a DeBrazza's infant and was detailed enough to answer questions that might be asked after the observation period was over.

There are many ways to collect behavioral data, and each methodology allows the researcher to ask certain types of questions. The use of a focal animal is very common, and important for determining activity budgets for individuals. The focus of this study was not on group dynamics or exhibit use, so group scans (recording the behavior and location of every individual in the group at certain times of day) were not appropriate (Crockett, 1996). I decided to use a timed instantaneous sampling protocol focused on one focal individual at a time (Crockett, 1996). Timed instantaneous focal animal sampling allows the researcher to establish an activity budget for each individual, as well as monitor behaviors over time. It is the mixed-taxa nature of this environment combined with the reproductive potential of the DeBrazza's monkey group that presents an important area for research, so the research design was established to account for these variables. However, the nature of the zoo setting makes it very difficult to avoid confounding variables, so although changes in behavior might correlate to some of the variables being studied, such as the birth of the infant, many other aspects of zoo life could also be attributed to those changes.

The study of animals living in captive populations is important because such investigation informs us about species-typical behaviors and how organisms interact with their environments, as well as ensuring the maintenance of healthy populations (Crockett, 1996; Hardy, 1996; Kleiman, 1992; Mallapur, 2005). As zoos change, and new ideas about proper zoo exhibits come into vogue, it is important to make certain that the new exhibits do not negatively affect the animals living in them (Maple, 2007). Although research has been done studying species that are closely related to DeBrazza's monkeys but not DeBrazza's themselves, and because cercopithecine primates are rarely housed in monogamous pairs and are seldom housed in mixed-taxa exhibits, this research is important and unique (Byrne, Conning, & Young, 1983).

This project seeks to generate data based on observations that can be used to monitor this group of DeBrazza's and ensure that both they and the Colobus are exhibiting normal behaviors as is understood by zoo professionals (AZA, 1998). The protocols emphasize social behaviors because of the mixed-taxa nature of the exhibit. The project also aims to make activity budgets for these animals that can then be used to compare to other captive groups of DeBrazza's as well as illustrate how the animals are using their exhibit. The activity budgets will be used to compare behaviors of the monkeys before and after the birth of an infant, and show patterns that could be compared to the patterns associated with the arrival of an infant in other single-species DeBrazza's monkey exhibits. We expect that the change in interaction between the mother and her previous offspring observed in other primate groups will be observed in these animals, and we predict that the adult male's behavior will also change after the infant's birth.

Methods

Subjects

The subjects in this investigation were 3 *Cercopithecus neglectus*: one adult male ('Otis') born August 4, 2001, one adult female ('Shama') born July 30, 2000, and one juvenile female ('Dafu') born July 29, 2009. An infant ('INF') was born December 10, 2010, but it was not included as a focal animal during any observations. They lived in an enclosure with three *Colobus guereza,* two *Potamochoerus porcus*, and a breeding family of *Procavia capensis.* This study was done in coordination with the MN Zoo Enrichment program, and all observations were made from the public viewing area during normal Zoo operating hours.

Facilities

The animals were housed inside the main building on the Tropics Trail of the Minnesota Zoo, Apple Valley Minnesota. The enclosure was designed to provide space for each species with trees and branches at varying levels for the primates, mulch and rock walls for the hyrax and hogs, and a waterfall for all of them. The DeBrazza's monkeys' diet consisted of monkey chow biscuits, fresh fruit and vegetables, and fresh browse (branches with leaves attached) when available. All animals were separated by species in holding areas when fed their daily diets, although food enrichment was often provided in the exhibit itself.

Procedure

The behaviors of the DeBrazza's monkeys were described *ad libitum*, or just as they occurred before a code was established; based on the descriptions, specific behaviors and categories were defined. In order to avoid inaccurate assumptions and the potential for anthropomorphism, behaviors were defined solely based on observable characteristics. For example, instead of "sleeping" the observer would describe the behavior based on observable characteristics such as "resting passive eyes closed" (see Appendix A). Behavioral observations were gathered over 20-minute long sessions using an instantaneous timed focal sampling procedure where every minute the behavior, location, and nearest neighbor of the focal animal was recorded. The distance between the nearest neighbor and the focal animal was estimated by the observer, as well as information regarding with whom the focal animal was interacting (during social behaviors). In addition, all occurrences of social behaviors with the focal animal were recorded (including information about the organism with whom the focal animal was interacting and details about the social behavior) in order to keep track of how the mixed-species nature of the exhibit influenced the behavior and sociality of the animals. Each day that sampling occurred, each DeBrazza's monkey's behavior was sampled for at least one sampling session. In order to avoid biases based on choosing to observe the monkey that was behaving most interestingly when the observer arrived to make observations (even if this behavior was not typical or common), the order of observation was predetermined: Otis was always observed first, Shama second, and Dafu third. Observations were made during winter zoo operating hours (between 9:00 am and 4:00

pm), and all behaviors were recorded from the public viewing area to ensure that the observer did not influence the monkeys' behaviors more than normal zoo visitor traffic might. *Ad libitum* observations (personal descriptions) were made as necessary that described keeper movements as well as other noises throughout the zoo. At the beginning of each sampling session the location of all of the DeBrazza's monkeys were recorded in order to establish where all of the individuals were spending time.

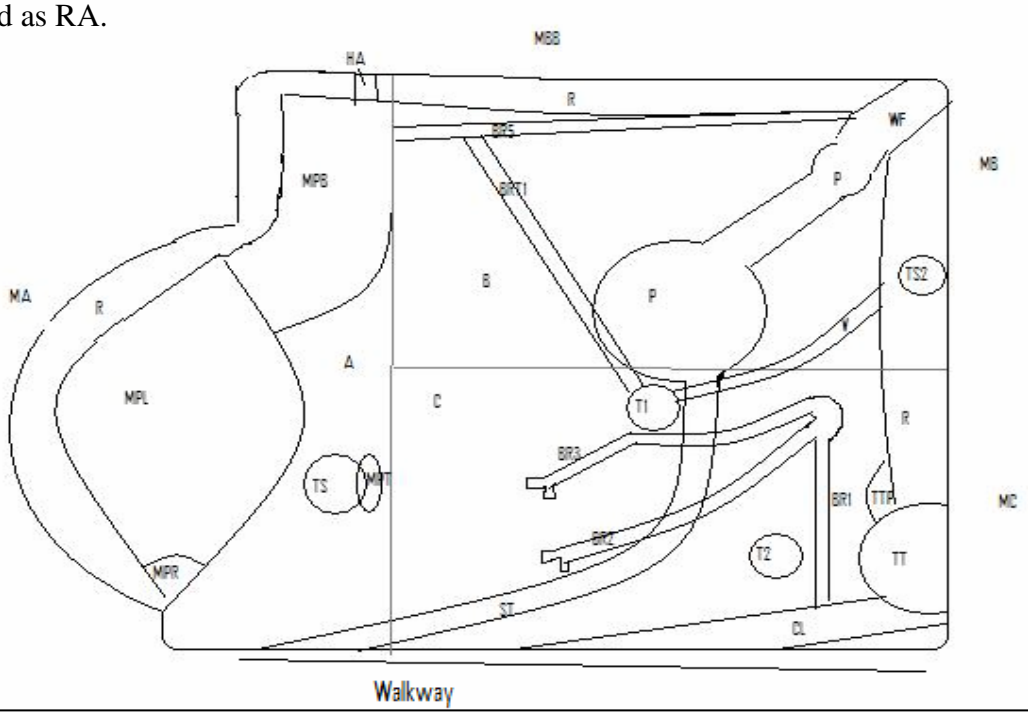
Ethogram Protocols

This ethogram was designed to establish an activity budget for the DeBrazza's monkeys at the MN Zoo. Behaviors that were sampled at the sampling points (i.e. every minute within the 20 minute sampling session) were recorded as belonging to a specific behavioral category. There were seven behavioral categories under which each behavior was characterized. These were: social behaviors, resting behaviors, grooming behaviors, food-related behaviors, locomotion, other, and out of view. Within each category there were specific behaviors that were observed in a sampling session. The observer determined the animal's behavior, noted the state and behavior of the animal, its location within the exhibit, as well as its nearest neighbor and approximate distance (in meters) from that neighbor. The first letter of the behavioral code established the behavioral category, and the subsequent letters determined the specific action within the state for behaviors recorded at the sampling points. All social behaviors of the focal animal were also recorded, and if they did not occur at a sampling point they were recorded as events with the code for the category (i.e. S for social) at the end of the behavioral code (SPA became PAS). Additionally, all parenting behaviors and grooming behaviors involving

other animals were recorded following the rules established for social behaviors not occurring at the sampling point.

When an infant was present in the exhibit, if the focal animal was the animal carrying the infant (who technically was the nearest neighbor), the next nearest neighbor was recorded, and the observer noted that the focal animal was carrying the infant. All other parenting behaviors were documented under social behaviors. Activities such as nursing the infant (which is not a behavior that is mutually exclusive to other behaviors) were recorded in addition to the other behavior being performed. For example, if at the sampling point the adult female was eating a leaf while the infant nursed, the eating was recorded first, followed by a comma and then the nursing was recorded second. Resting behaviors were also noted if performed while nursing. Because the infant's behavior was not recorded, nursing was only recorded when the adult female was the focal animal. The infant could, however, still be the recipient of social behaviors. It was important to separate behaviors performed by the infant or by the adult carrying the infant. If the focal animal approached the animal carrying the infant, both the animal carrying the infant and the infant were recorded as the individuals receiving the action with the older animal recorded first followed by a comma and the code INF for infant. If the focal animal was approached by an animal carrying the infant, the behavior was recorded as having been received from the adult alone because the infant had nothing to do with the approaching behavior. If the nearest neighbor of the focal animal was the individual carrying the infant, both the adult and the infant were recorded with the code for the adult being recorded first followed by a comma and the code for the infant.

At the beginning of each sampling session the start time was recorded. Observations that started between 9:00 am and 11:30 am were subsequently coded as "morning," between 11:31 am and 1:30 pm as "midday" and between 1:31 pm and 4:00 pm as "afternoon." The codes for the spaces within the exhibit were located on the diagram of the enclosure (see image below). The exhibit was divided into three main sections: A, B, and C. The labels for the objects were based on where each item was located, and how it related to other items in the exhibit. If a monkey was on a branch of T2, it was recorded as BRT2, or if a monkey was on the rock wall in section A it was recorded as RA.



Legend:

CL: Climbing Log	TT: Training Tree
P: Pool	WF: Waterfall
MPL: Mulch Pit Left	MPB: Mulch Pit Bottom
ST: Stream	TS: Tree Stump
MPT: Mulch pit tree stump	R: Rock (wall)
T: Tree	BR: Branch
M: Mesh	P: Planter
V: Vines	HA: Holding Area
TTP: Training tree planter	

A, B, or C: Larger section of exhibit (used to describe locations of other exhibit objects)

Data Analysis

Because a primary purpose of the project was to assess the effectiveness of the ethogram and protocols, mainly descriptive statistics were used. Figures of the patterns of the breakdown of behaviors and descriptive statistics are effective when evaluating the methodology and general behaviors observed because they allow the whole picture to be seen as well as show where further research or data collection is needed. However, for some of the patterns observed in this study, I did use inferential statistics to test for significance in the behavioral differences observed. In order to determine whether these differences between pre- and post-infant observations were statistically significant, each sampling session was used on its own. T-tests were used to calculate whether each animal spent significantly different amounts of time nearest other particular animals. Two different types of t-tests were used: both unpaired and paired. In behavioral neuroscience research there is a general precedent that all behavioral data collected, even from the same animal, is not paired with any other data collected and is thought to be independent of all other behaviors. This would lead to using an unpaired t-test and assuming that, because there could be no interaction with the infant before the infant was born, the pre-infant observations were inherently unpaired from the post-infant observations. However, observations were being made on the same animals with a change in one variable (the inclusion of the infant), so I also used a paired t-test to see whether these two methodologies yielded different significance results. Because more observations were made post-infant than pre-infant, a subset of the data points was randomly chosen to be used in the paired t-test. In order to avoid biases based on my

own experiences observing the animals, I used a random number generator to determine which sampling sessions post-infant would be used to compare to the pre-infant data. However, both t-tests yielded the same results regarding the significance of the observed differences. In the results section, all of the t-values reported are for the randomly paired data set.

Results and Discussion

Activity budgets for the DeBrazza's monkeys at the Minnesota Zoo were calculated both before and after the birth of the infant. Before the infant was born, the two adults spent the majority of their time resting, while the juvenile was much more active, spending the majority of her time doing food-related activities. After the birth of the infant the adult female, Shama, spent the majority of her time parenting. Figures 1, 2 and 3 show the activity budgets of all three DeBrazza's monkeys before and after the birth of the infant, and how they compare to each other. Figure 4 shows the breakdown of parenting behaviors displayed by Shama post-infant. Nursing represented 43% of the parenting behaviors observed.

I was also interested in how the animals interacted with each other. All of the DeBrazza's spent the majority of their time near other DeBrazza's, both before and after the birth of the infant. Before the birth of the infant, Otis (the adult male) spent 35% of his time closest to Dafu (the juvenile) and 29% of his time closest to Shama (the adult female). After the birth of the infant he spent 48% of his time closest to Dafu and 24% of his time closest to Shama. Additionally, 23% of the time that he was closest to Shama,

she was carrying the infant. There was no statistically significant difference in the amount of time he spent nearest Dafu or Shama comparing across pre- and post-infant. However, Otis did spend significantly more time nearest to the Colobus before the infant was born (15% of his time) than after (5% of his time), $t(9)=4.16$, p=.002 (Figure 5). Otis also spent 15% of his time close to the hyraxes pre-infant and 18% of his time closest to them post-infant.

Before the infant was born, Shama spent 46% of her time near Otis and 40% of her time near Dafu. After the birth of the infant, Shama carried the infant 85% of the time. She also spent 36% of her time closest to Otis, and 23% of her time closest to Dafu which was significantly less time than pre-infant, $t(9)=3.025$, p=.014. This was the only significant difference she displayed between pre- and post-infant for nearest neighbor. Additionally, 12% of Shama's time was spent near the infant, but not carrying it. Shama also spent around 9% of her time near the hogs, both before and after the birth of the infant. Surprisingly, Shama spent more time near the Colobus post-infant (10% of her time) than pre-infant (2% of her time), although this difference is not significant (Figure 6).

Dafu spent significantly more time near Shama pre-infant (35%) than post infant (15%), $t(9)=2.49$, p=.034. The differences in her time spent nearest to Otis were marginally significant, with her spending 32% of her time closest to Otis pre-infant and 53% of her time post infant, $t(9)=2.13$, p=.061. Both before and after the birth of the infant Dafu spent around 10% of her time closest to the hyraxes. Additionally she spent 9% of her time near the Colobus pre-infant, and 7% of her time near them post-birth

(Figure 7). The data regarding nearest neighbor is important because it sheds light on how the mixed-taxa exhibit is influencing the behavior of the DeBrazza's monkeys as well as shows with which animals the DeBrazza's are spending time close to.

To more specifically look at with whom the DeBrazza's were interacting socially, the data regarding their partners in social interactions was collected. Before the infant was born, 15% of Otis's social interactions were with Shama, and after the infant was born 12% of his social behavior was directed towards her (4% of that time was spent interacting with Shama and the infant). Pre-infant, Otis spent 53% of his social interactions engaged with Dafu and post-infant 46% of his social interactions. Before the infant was born, 28% of Otis's social encounters were with the Colobus and after the infant was born 39% of his social interactions were with Colobus (Figure 8). Shama spent 18% of her social interactions with Otis pre-infant, and 5% post-infant. Additionally, pre-infant 72% of Shama's social interactions were with Dafu, while post-infant only 12% of her social interactions were with Dafu (Figure 9). Pre-infant, Dafu interacted with Shama 17% of her social interactions, and post-infant she only interacted with Shama for 14% of her social interactions (10% of which were interacting with Shama and the infant). Furthermore Dafu spent 38% of her social interactions with Otis pre-infant and 34% of her social interactions post-infant (Figure 10).

Figure 11 shows the breakdown of time of day for Otis, both pre-and post-infant. Pre-infant, no observations of Otis were made midday. Figure 12 is the breakdown by time of day for Shama, and figure 13 shows the breakdown for Dafu. The three most common behaviors (resting, moving, and feeding) were observed at all times of day, and

each individual showed a unique pattern of behaviors at each time of day. Some of the high percentages may be due to relatively few data points during that time period.

These results show how the DeBrazza's were behaving during the sampling period as well as show what information can be gleaned from the data collected with the ethogram.

Conclusions

This project sought to construct an ethogram that could effectively establish activity budgets for DeBrazza's monkeys living in a unique mixed-taxa exhibit. The purpose of establishing activity budgets for these animals was to get a sense of how they spend their time, and potentially explore the effects of living in a mixed-taxa exhibit while being reproductively active. Additionally, the birth of an infant represented a huge change within the exhibit, so comparing activity budgets and behaviors across this addition to the group might show how an infant affects behavior within a group, especially in this mixed-taxa setting. However, the unexpected birth of the infant shed light on some of the challenges associated with the ethogram as it was constructed.

Before the infant was born, both adult DeBrazza's spent the majority of their time resting. This continued to be the case for the adult male, but after the birth of the infant the adult female spent most of her time parenting. This was to be expected, and not all parenting behaviors required the female to be active. The female did continue to rest while nursing or carrying the infant, but because she was caring for the infant it was coded as parenting. This discrepancy emphasizes the most challenging aspect of the

ethogram construction. Because parenting behaviors are not mutually exclusive from other behaviors, they do not fit within the established rules for behaviors that can be recorded. The adult female can nurse her infant while she eats something herself. Should this be recorded as nursing, or eating? If the study were specifically focused on parenting behaviors, the nursing would be the primary behavior; this study was more generalized, so both the feeding behavior and the nursing behavior were recorded. But then, during data analysis, which behavior should be primary? For the purpose of making an activity budget, I decided that any parenting behaviors done in combination with resting behaviors would be coded as parenting, while any other behaviors would be considered primary and included as those behaviors for the purpose of comparison from pre-infant to post-infant. The parenting behaviors are also important, so I looked at parenting behaviors separately in order to understand how Shama was interacting with the infant. Nursing was the most common parenting behavior, and the infant was often carried ventrally, allowing easy access to the nipples much of the time. The high rate of nursing behavior may seem like an incredibly high energetic burden placed on the mother, but there is no way to be sure whether there was any nutrient transfer occurring during the times that nursing was observed. All that could be observed was the infant's mouth on the mammary tissue of the female; consumption of milk could not be verified, which is another challenge associated with purely observational research.

It is also important to recognize that comparing Shama's behavior before and after the birth of the infant is to compare her behavior while pregnant to her behavior while caring for an entirely dependent offspring. Both of these states have high energetic

requirements, so Shama's overall lack of behaviors that require a lot of energy (i.e. locomotion) might be related to her need to conserve as much energy as possible. Her previous offspring, at the time of observation, was a completely independent juvenile, who did not require much maternal care. Fairbanks (2003) described a pattern of maternal care in which the amount of mother-offspring interaction greatly decreases after the birth of a new infant. This pattern can be observed in this data set as well. The majority (72%) of Shama's social interactions before the new infant was born were with Dafu (the previous offspring). After the birth of the infant only 12% of Shama's social interactions were with Dafu. Dafu was also Shama's nearest neighbor significantly less time post-infant than pre-infant. The second part of this pattern is that the yearling when rebuffed by its mother spends more time near other individuals within the group (Fairbanks 2003). This was also observed in this group, with Otis as Dafu's nearest neighbor more post-infant than pre-infant. This shows that some of the more generalizable patterns in primate parenting were observed in this situation. The mixed-taxa nature of the exhibit did not cause the adult female to try to parent both her previous and current dependent offspring, and the yearling reacted to the lack of maternal care like other young primates that live in different types of settings do. Additionally, the female juvenile was observed alloparenting and interacting with the infant, and on a couple of occasions did in fact groom and watch over the infant while the adult female was a couple meters away. The female was always watchful (personal observation) and did not let these interactions last long. This also reinforces the previous research on primate groups and parental strategies.

The data regarding each animal's nearest neighbor were also very interesting. Given the understanding that the adult male often plays the role of protector within a group, I was interested to see whether his proximity to the Colobus changed after the infant (an individual requiring protection) was born. I was surprised to find that Otis actually spent significantly less time near the Colobus after the birth of the infant. I thought that this might be explained by spending more time near Shama and the infant, but this was not supported by the data. There are many other factors that might have caused Otis to spend less time near the Colobus. Perhaps the Colobus changed their behavior, and Otis's patterns of exhibit use did not change. The weather might also have played a role, because many of the pre-infant observations were made before winter really hit in Minnesota, while most of the post-infant observations were made in the heart of January. Even though the animals are housed inside, the weather affects things like daylight, as well as the number of zoo visitors on any given day. These can all be part of the explanation for any of the patterns observed in this data, so while the birth of the infant most likely played a role in some of the observed changes, the inability to design controlled experiments in a zoo setting renders impossible a determination of which variable accounts for which observed change. Additionally, although Otis spent less time near the Colobus post-infant, he continued to interact with them socially at a high rate. So although he didn't stay close to the Colobus after the infant was born, he did continue to watch them and threaten them when they got too close. Changes that might be observed in Dafu's behavior can also be explained by her continued development. She was a little over one year old when the study began, and during the three months over

which observations took place Dafu continued to mature. Many of the changes in her behavior might be associated to this rather than the birth of the infant.

Many explanations also exist for the observed time of day patterns. The daily zoo routine itself may play an important role in determining how the monkeys behave at different points. For example, browse and other food items are put out in the morning before the animals are let into the exhibit. The monkeys thus spend more time in the morning eating than in the afternoon, because by the afternoon most of the food put out in the morning has been consumed. Furthermore, because the monkeys move from a holding area into the exhibit every morning, and often the exhibit has been cleaned or enrichment items have been put in, the monkeys take time in the morning to explore what is new and to reclaim their preferred territories. This all can influence the activity budgets of the animals based on time of day. The number of visitors at any particular time of day might also influence the behaviors exhibited by the primates; there are fewer visitors early in the morning and late in the afternoon, which might affect the animals' stress levels.

In order to more effectively demonstrate the effects of the mixed-taxa nature of this zoo exhibit on the behavior of this group of DeBrazza's monkeys, comparisons to the behavior of other captive DeBrazza's populations that are in different types of enclosures should be made. I contacted a number of zoos around the country that have populations of DeBrazza's, but unfortunately, none of them were able to provide me with activity budgets of their populations. Moreover, very few had groups of DeBrazza's that were reproductively active. Future research should include behavioral observations at other

institutions in order to make comparisons across exhibit type and group structure. It is important to use the same methodology in order to have the ability to make direct comparisons. The ethogram and protocols that were designed for this project can be used at any zoo, and future research should seek to explore some of the patterns that were observed in this project.

The process of designing an ethogram is complicated. Not only does it involve observing the animals' behaviors in order to identify and define all behaviors that might be used later, but it also involves thinking about the questions that you want to ask, as well as deciding how the data will be analyzed. One has to account for unexpected changes in the environment and group structure, and determine how this will influence the questions asked and the analysis of future data. When the question of parenting arises, it is also important to make sure that parenting behaviors can be recorded without losing valuable information regarding the behavior and state of the parent, especially if one want to ask more general questions about overall behaviors exhibited. It is not always a central imperative to look at whether differences are observed because of a change in one particular variable. Examining the patterns of behavior, and how they change over time, can have useful implications for maintaining healthy zoo populations. For this particular population it appears that there have been few agonistic encounters between the species in the exhibit, and therefore this grouping of species and individuals seems to be a success.

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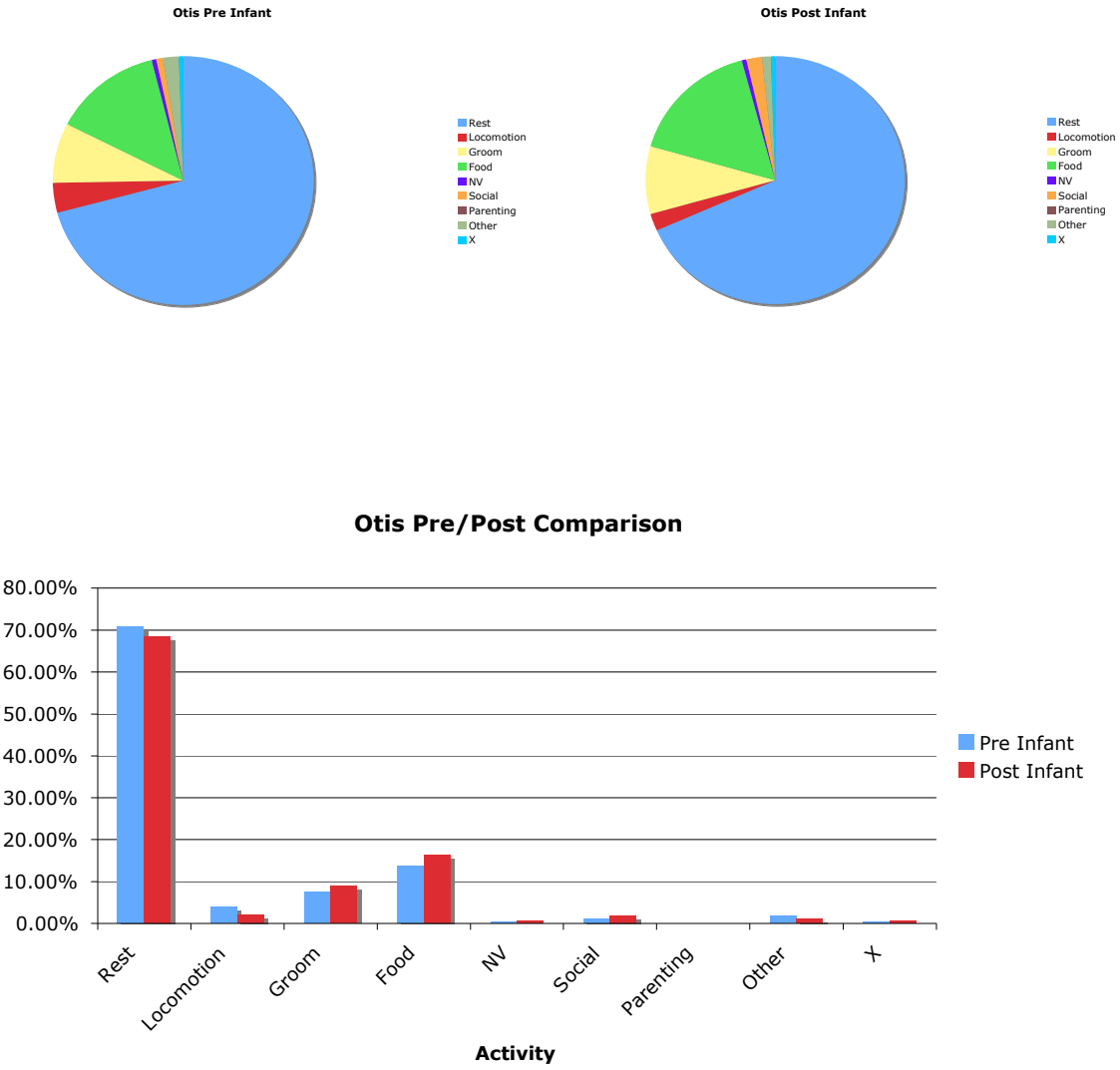

Figure 2. *Otis activity budgets: Pre and post infant comparison.* This figure show the breakdown of activities for Otis, and it directly compares pre- and post-infant behaviors. Pre-infant Otis spent 71% of his time resting, 14% of his time in food related activities, 8% of his time grooming, and 4% of his time moving around. Post-infant Otis spent 69% of his time resting, 17% of his time in food-related activities, 9% of his time grooming, and 2% of his time moving around. NV stands for no view, and X stands for unknown.

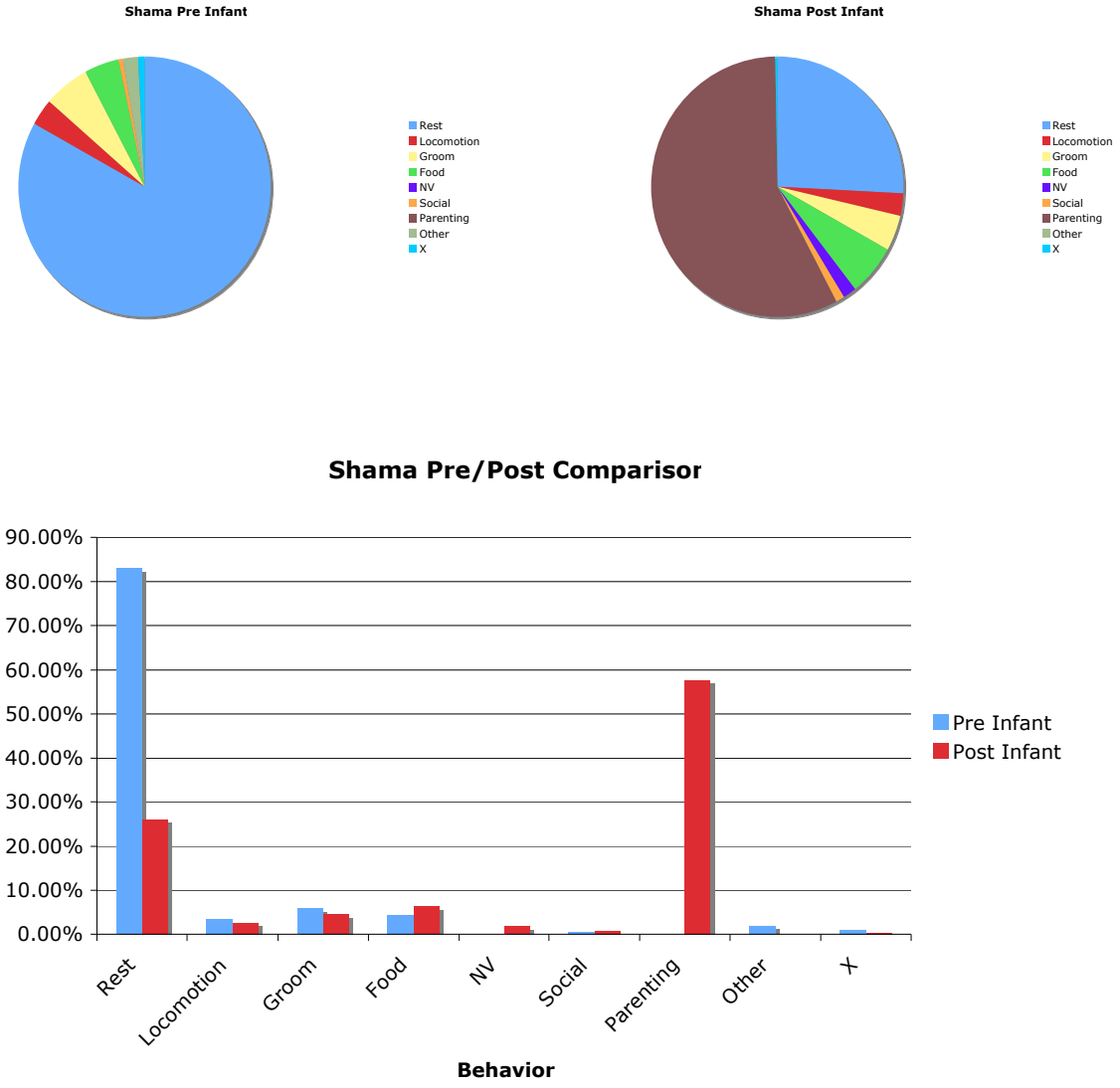

Figure 4. *Shama activity budgets: Pre and post infant comparison.* This figure show the breakdown of activities for Shama, and it directly compares pre- and post-infant behaviors. Parenting in this figure includes parenting behaviors done on their own and parenting behaviors done while resting (not behaviors that were done in combination with another more active behavior). Pre-infant Shama spent 83% of her time resting, 4% of her time in food related activities, 6% of her time grooming, and 3% of her time moving around. Post-infant Shama spent 26% of her time resting (no parenting), 4% of her time in food-related activities, 2% of her time grooming, and 1% of her time moving around. She also spent 66% of her time parenting. NV stands for no view, and X stands for unknown.

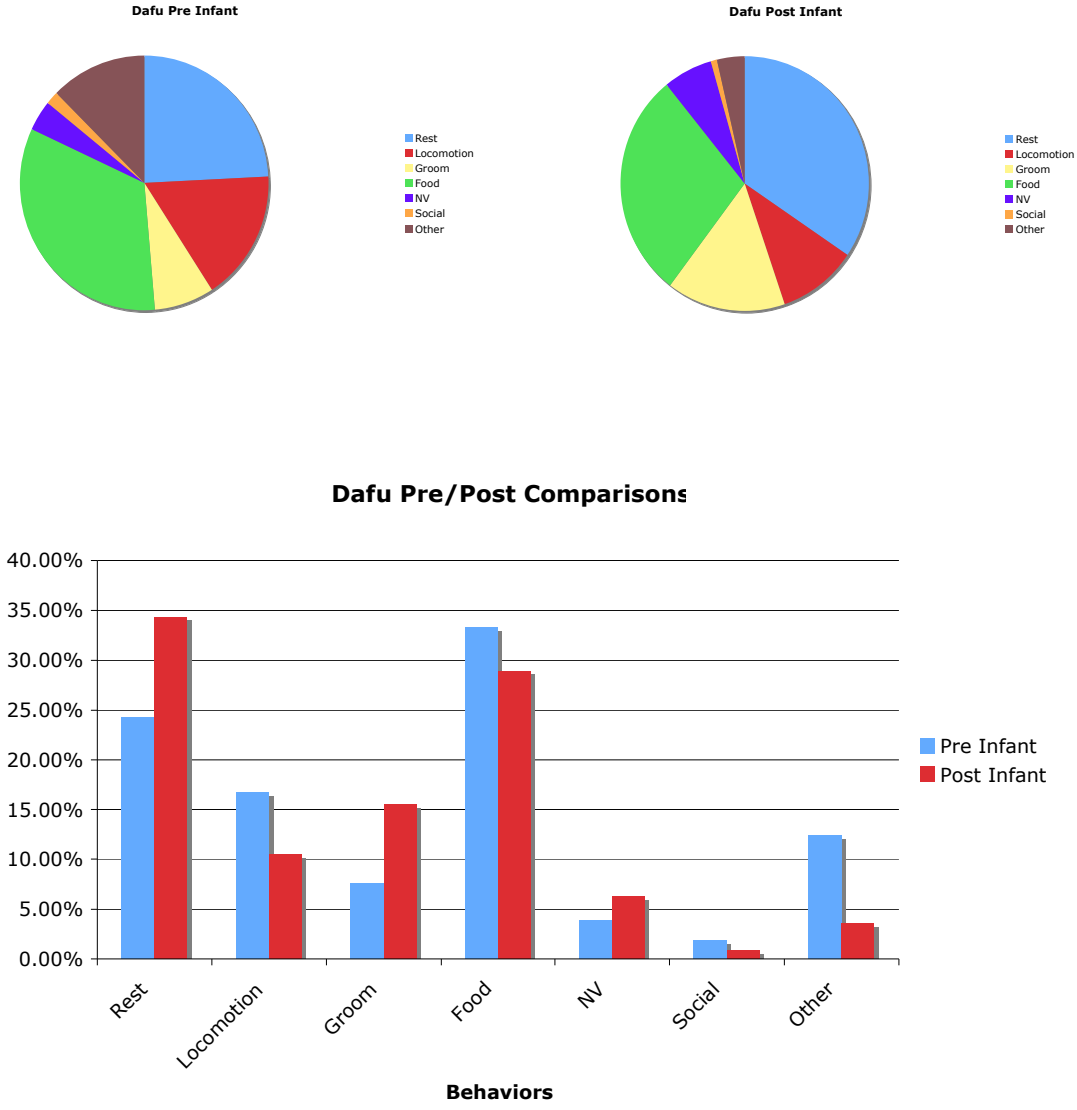

Figure 5. *Dafu activity budgets: Pre and post infant comparison.* This figure show the breakdown of activities for Dafu, and it directly compares pre- and post-infant behaviors. Pre-infant Dafu spent 24% of her time resting, 33% of her time in food related activities, 8% of her time grooming, and 17% of her time moving around. Post-infant Dafu spent 34% of her time resting, 29% of her time in food-related activities, 16% of her time grooming, and 11% of her time moving around. NV stands for no view, and X stands for unknown.

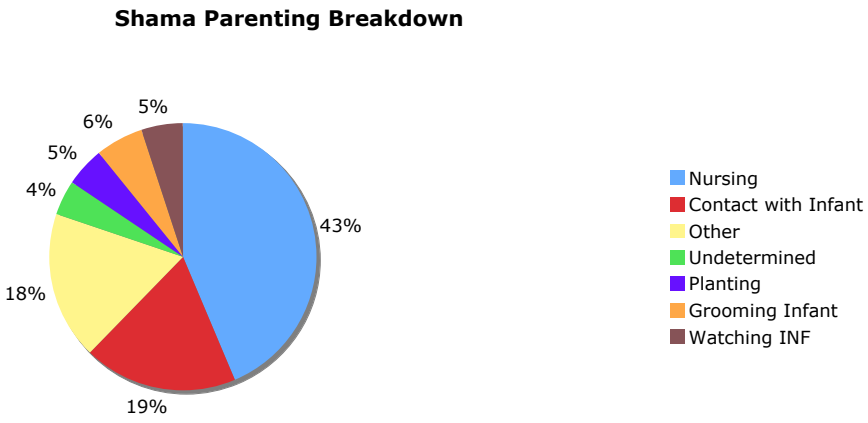

Figure 6. *Shama parenting behaviors.* This figure shows the percentage of parenting behaviors each specific behavior represented. 43% of parenting behaviors were nursing, and 19% were just carrying the infant. 6% included grooming the infant and 5% included watching the infant. These behaviors include those parenting behaviors exhibited while also doing something else.

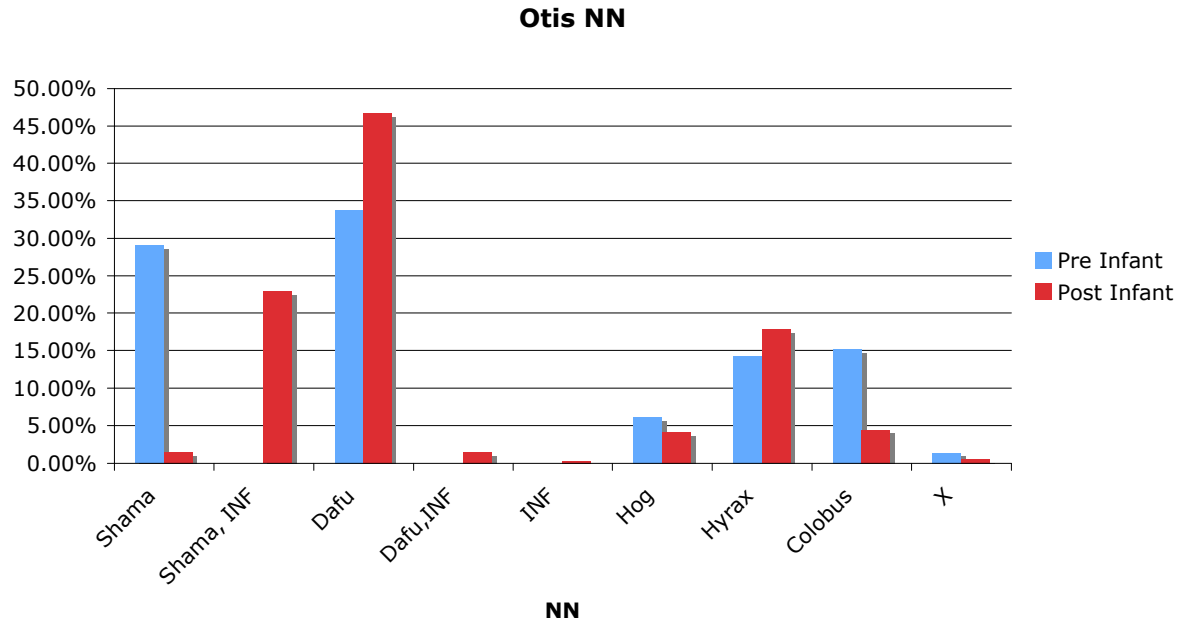

Figure 7. *Otis nearest neighbor comparison.* This graph shows the nearest neighbor breakdown for Otis. The bars represent the percentage of the total observations that Shama was closest to each individual. Those categories containing two individuals separated by a comma are instances when Otis was equidistant from both, and INF stands for infant. X stands for unknown.

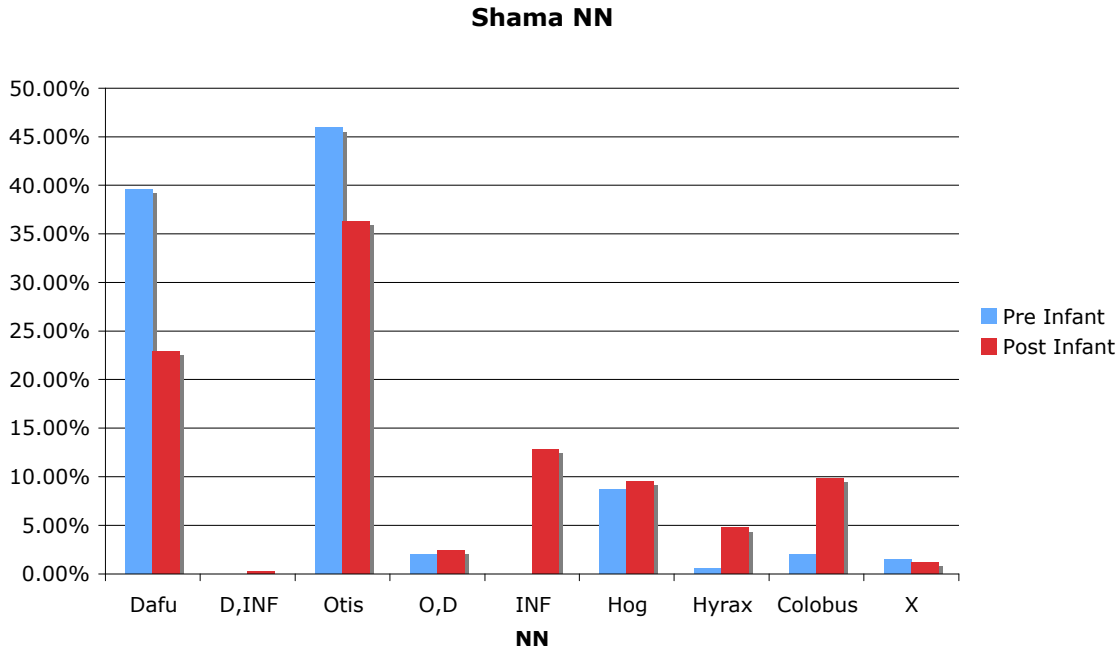

Figure 8. *Shama nearest neighbor comparison.* This graph shows the nearest neighbor breakdown for Shama. The bars represent the percentage of the total observations that Shama was closest to each individual. Those categories containing two individuals separated by a comma are instances when Shama was equidistant from both, and "O" and "D" stand for Otis and Dafu respectively, while INF stands for infant and X stands for unknown.

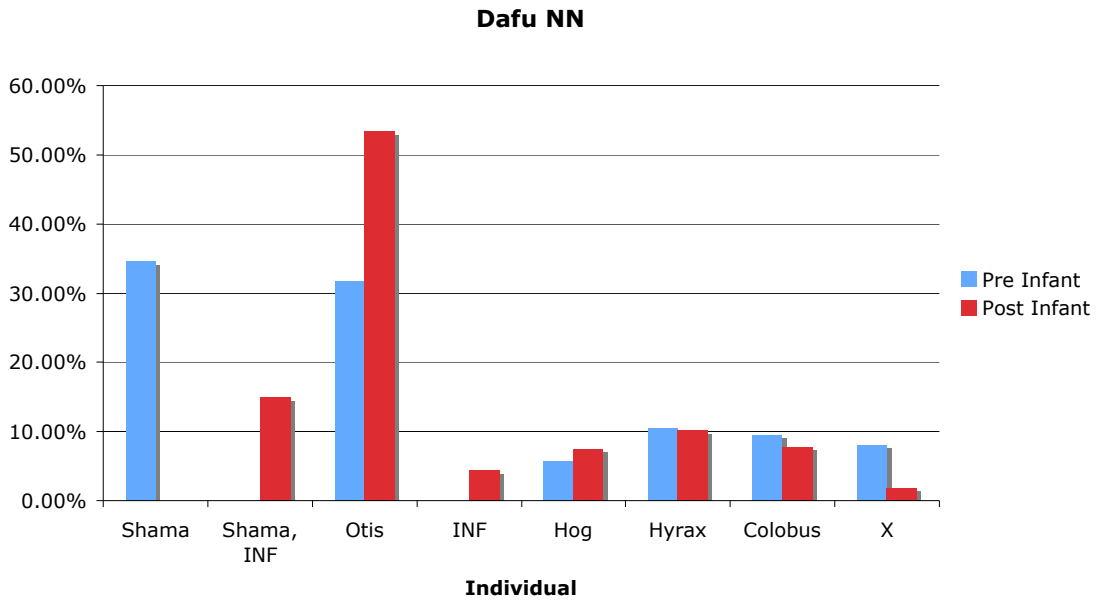

Figure 9. *Dafu nearest neighbor comparison.* This graph shows the nearest neighbor breakdown for Dafu. The bars represent the percentage of the total observations that Dafu was closest to each individual. Those categories containing two individuals separated by a comma are instances when Dafu was equidistant from both. INF stands for infant, and X stands for unknown.

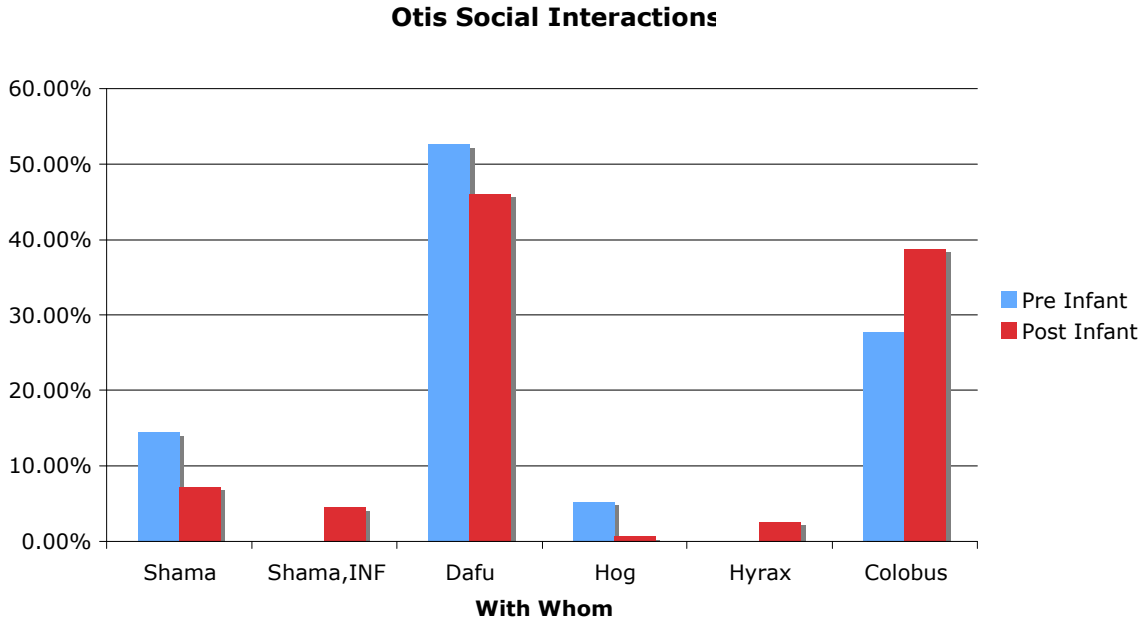

Figure 10. *Otis social interactions*. This figure shows the break down of with whom Otis interacted when he engaged in social interactions. Each bar shows the percentage of social interactions Otis engaged in with each individual. INF stands for infant.

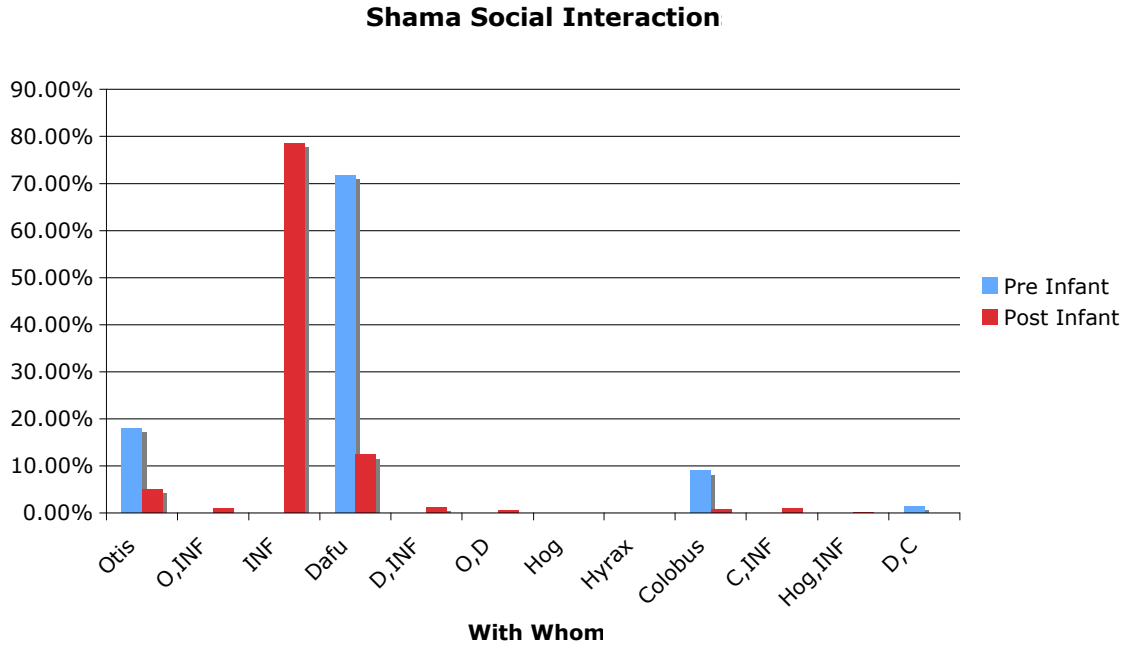

Figure 11. *Shama social interactions*. This figure shows the break down of with whom Shama interacted when she engaged in social interactions. Each bar shows the percentage of social interactions Shama engaged in with each individual. INF stands for infant, O stands for Otis, D for Dafu, and C for Colobus. Additionally, categories containing two individuals separated by a comma means that Shama was interacting with both of them, and when the infant was the second individual listed it means that Shama was engaging in parenting behavior while interacting socially with another individual.

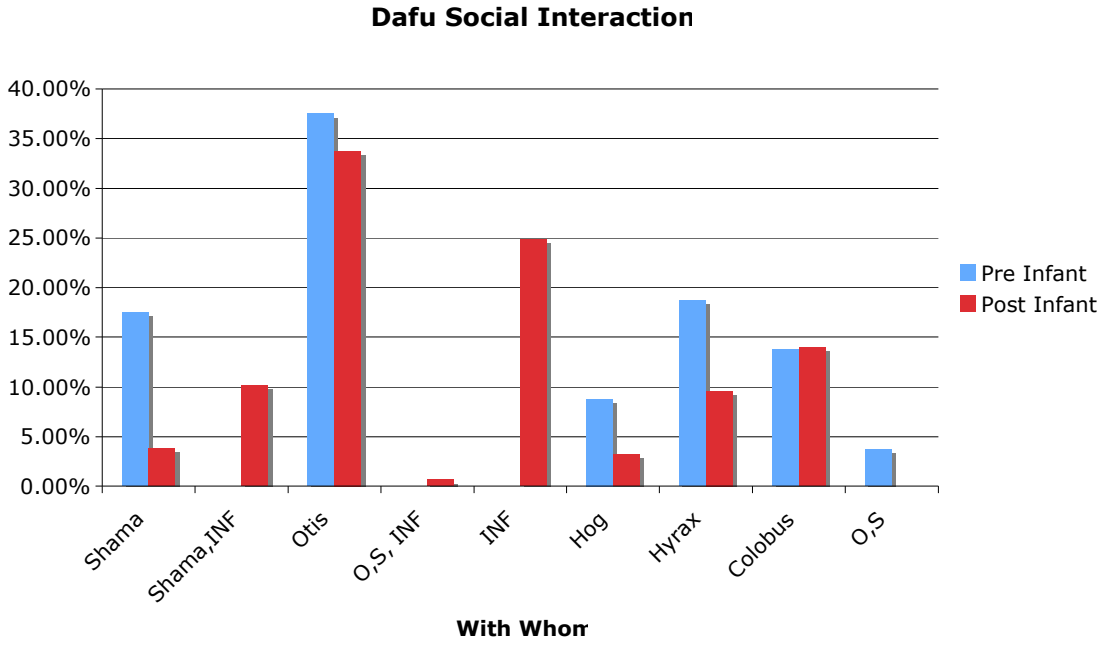

Figure 12. *Dafu social interactions*. This figure shows the break down of with whom Dafu interacted when she engaged in social interactions. Each bar shows the percentage of social interactions Dafu engaged in with each individual. INF stands for infant, O stands for Otis, D for Dafu, and S for Shama. Additionally, categories containing two individuals separated by a comma means that Dafu was interacting with both of them.

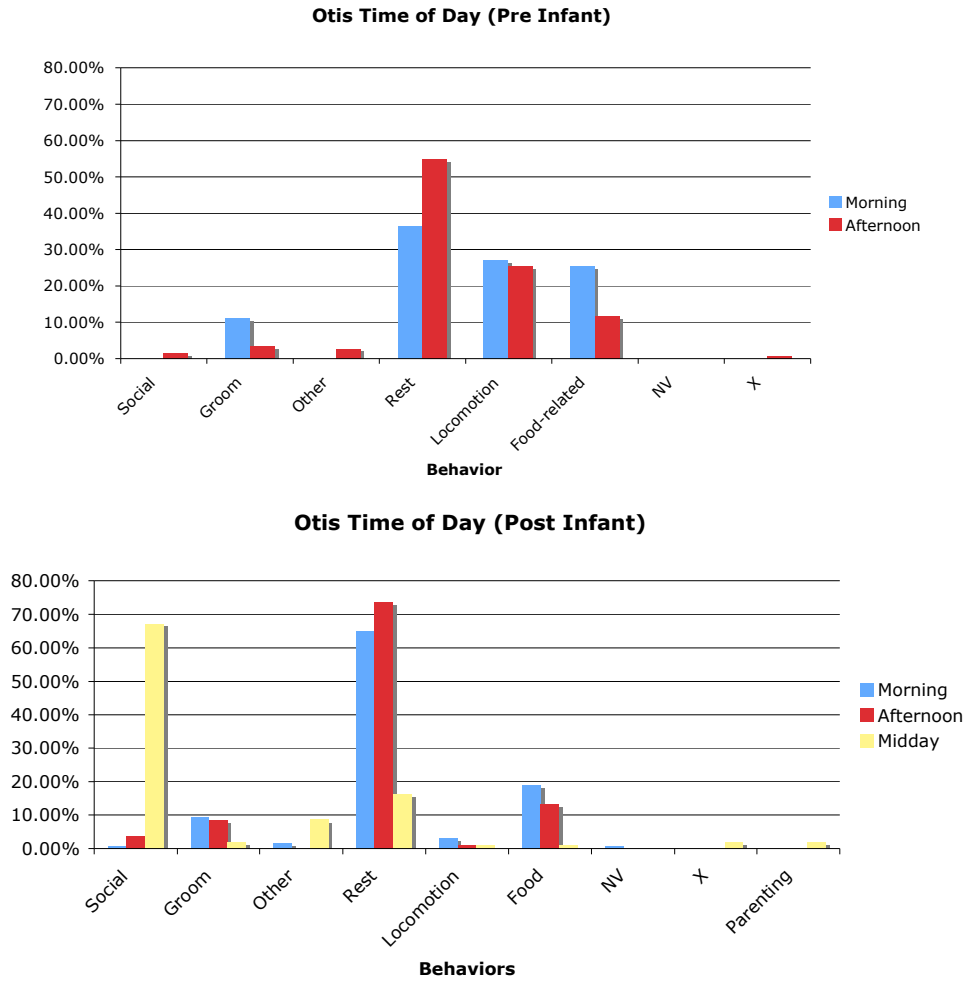

Figure 13. *Otis time of day comparisons.* This figure shows the breakdown of behaviors by time of day. Pre- and post-infant are shown separately. Pre-infant no observations were made of Otis during the midday time period. NV stands for no view, and X stands for unknown.

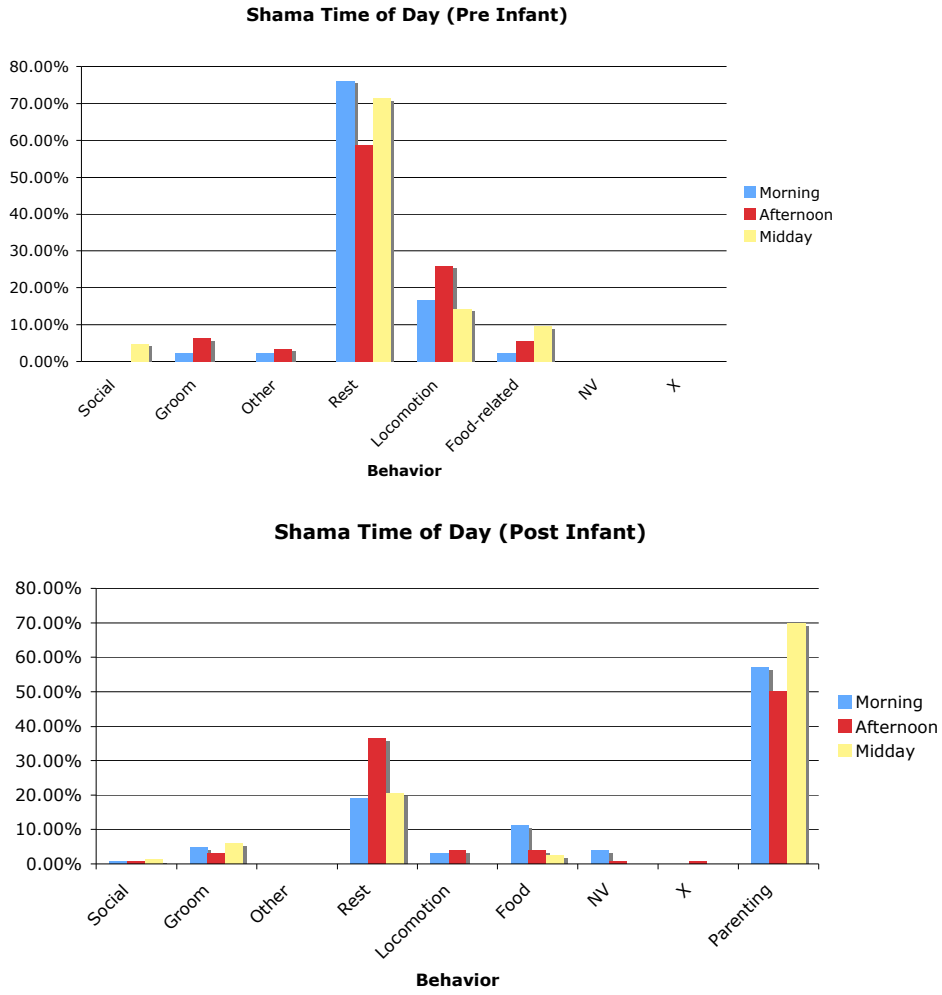

Figure 14. *Shama time of day comparisons.* This figure shows the breakdown of behaviors by time of day. Pre- and post-infant are shown separately. The parenting behaviors are those done alone or in combination with resting behaviors. All other behaviors done in combination with parenting were counted as the non-parenting behavior. NV stands for no view, and X stands for unknown.

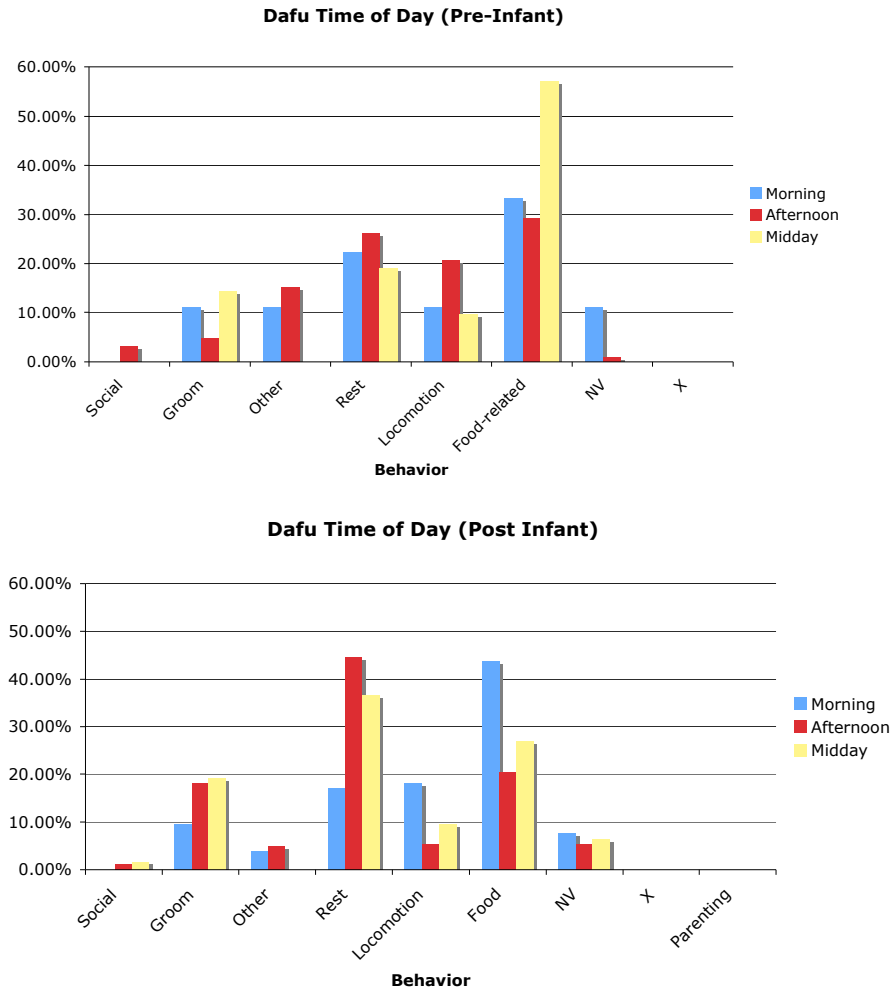

Figure 15. *Dafu time of day comparisons.* This figure shows the breakdown of behaviors by time of day. Pre- and post-infant are shown separately. NV stands for no view, and X stands for unknown.

Appendix A

Ethogram

The first letter of the behavioral code establishes the behavioral state, and the subsequent letters determines the specific action within the state for behaviors recorded at the sampling points.

Rest

The focal animal is not moving. It may be resting vigilantly (i.e. looking around) and alert, or it may be resting passively (i.e. lying down relaxed).

RPO – Resting passive eyes open – motionless, passive, eyes open
RPC – Resting passive eyes closed – motionless, passive, eyes closed
RPX – Resting passive unknown – motionless, passive, cannot tell if eyes are open or closed
RVS – Resting vigilant social – motionless, looking in the direction of another animal (note the animal name or species in parentheses)
RVO – Rest vigilant observer – motionless, looking in the direction of the observer
RVK – Rest vigilant keeper – motionless, looking in the direction of a keeper
RVP – Rest vigilant public – motionless, looking in the direction of the public
RVE – Rest vigilant environment – motionless, looking at something within the exhibit, but not at another animal
RVX – Rest vigilant unknown – motionless looking at something unknown
RXX – Rest undetermined – motionless but can't tell if passive or vigilant

Locomotion

The focal animal moves from point A to point B.

LWT – Locomote walk terrestrial – non-vertical quadrapedal movement with two or more feet moving slowly on the ground or rock formations
LWA – Locomote walk arboreal – non-vertical quadrapedal movement with two or more feet moving slowly in the trees/branches
LRT - Locomote run terrestrial – non-vertical quadrapedal movement with two or more feet moving quickly on the ground or rock formations
LRA – Locomote run arboreal – non-vertical quadrapedal movement with two or more feet moving quickly in the trees/branches
LJ – Locomote jump – movement in which all four feet leave the substrate at one time
LC – Locomote climb – vertical movement up or down a substrate or object (such as the mesh)

Grooming

The focal animal engages in a grooming bout, either alone or with another individual. Individuals will be noted in the log.

GPA – Groom present actor – exposes a part of the body to solicit grooming
GPR – groom present recipient – grooms an other animal that presents itself for grooming
GAU – Autogroom – uses own hands or mouth to clean own skin or fur
GAL - Allogroom – focal animal uses own hands or mouth to clean the fur or skin of another individual (noted in parentheses)
GM – Mutual groom – grooming and being groomed at the same time (other actor noted in parentheses)
GR – Groom recipient- being groomed by another individual (noted in parentheses)
GX – Groom unknown – cannot tell if being groomed or is grooming
GS – Groom scratch – uses hands to scratch self, but not actively cleaning

Food-Related

The focal animal is searching for, manipulating, or eating food on exhibit.

FH – Food hold – holding food item in hands while moving (describe food item)
FCE – Food chewing and eating – chewing/eating while sitting/resting (describe food item if possible)
FR – Food rub – rubbing food item with hands before consuming (describe food item if possible)
FM – Food manipulate – use the hands or mouth to manipulate the food item before eating (i.e. removing the husk from a piece of fruit, note type of manipulation and food item)
FN – Nursing – feeding from mother's breast (scored for both mother and infant)
FG – Gnawing – chewing or licking paint or covering off of items in exhibit (describe object getting chewed)
FFB – Foraging browse – searching/manipulating browse prior to consumption
FFO – Foraging other – searching through/manipulating other objects (or plants) on exhibit prior to consumption (describe food item)
FD – Drink – consuming liquid from pool etc.

Out of View

NV – No view – animal cannot be seen, and behavior cannot be determined

Social

Behaviors that involve more than one individual interacting in some way. Always note which individuals besides the focal animal are involved in each behavior (noting species when individual is unclear)

SC – Social contact – focal animal remains sitting or lying for at least 10 seconds in contact with another individual who is resting (noting the individual in the log)
SAA – Intraspecies aggression – one individual may be grabbing, hitting or biting another conspecific (in the notes describe who is aggressing and who is receiving aggression as well as who may have started it, as related to the focal animal)
SAE – Interspecies aggression – one individual may be grabbing, hitting or biting a member of another species (in the notes describe who is aggressing and who is receiving aggression as well as who may have started it, as related to the focal animal)
SMO – Mount/Mate – the focal animal mounts another individual while moving its pelvis repeatedly, or the focal animal is mounted while the other individual moves its pelvis repeatedly
SIA – Social inspect actor – sniffing, licking, or exploring the genital area of another individual
SIR – Social inspect recipient – another individual sniffs, licks or explores the genital area of the focal
SIM – Social inspect mutual – the focal and another individual sniff, lick or explores each other's genitals at the same time
SFS – Social food share – the focal feeds from the same piece of food that another individual is feeding from (without animosity from either) (note the individual involved, and which individual had the food first)
SDA – Displace actor – the focal moves towards another individual and stays put while the other individual moves away
SDR – Displace recipient – individual moves towards the focal animal and stays put while the focal animal moves away
SPA – Approach actor – focal moves within .5m of another individual and stays for at least 3 sec
SPR – Approach recipient – individual moves within .5m of focal and stays for at least 3 sec
SCA – Chase actor – focal moves rapidly towards an individual while that individual moves rapidly to stay away from focal animal
SCR – Chase recipient – individual moves rapidly towards focal while focal moves rapidly to stay away from individual
SNN – Nose to nose – focal and other animal bring noses within a few centimeters of one another
SH – Huddle – two or more monkeys nestled closely together in contact
SRH – Roughhousing – two or more monkeys wrestling, more playlike than aggressive
FRA+ - Food rob actor successful – the focal successfully grabs a piece of food from another individual, with the individual offering resistance (note the individual)

FRA- - Food rob actor unsuccessful – the focal unsuccessfully grabs a piece of food from another individual, with the individual offering resistance (note the individual)
FRR+ - Food rob recipient successful – another individual successfully grabs a piece of food from the focal animal, with the focal offering resistance (note the individual)
FRR- - Food rob recipient unsuccessful – another individual unsuccessfully grabs a piece of food from the focal animal, with the focal offering resistance (note the individual)
SST – Social Stare – directed open eye gaze with the exposure of the lightly colored eyelids
SHB – Social head bob – forward and downward movement of the head accompanied by stare
ST – Social Treat – Threatening, territorial behavior such as biting own arm at animal (aggressive but no physical contact).
SO – Social Other – other behavior involving the focal and at least one other animal. Is described in notes
SPN – Social Nursing – infant has mouth in contact with focal animal's nipple or mammary tissue. If done in combination with another behavior (including resting) record that behavior followed by a comma and SPN.
SPO – Social Parenting Other – focal animal does other parenting behavior such as adjusting infant that it is carrying, or facilitating nursing by taking own nipple and putting it in infant's mouth that is not already covered by other behavior codes. Record the details in comments
SPX- Social parenting unknown – focal animal interacting with infant but out of view of the observer
SPP – Planting – animal carrying the infant puts infant down and steps away. (Start and end time recorded in notes).

<u>Other</u>

Behaviors observed not directly characterizable into above behavior states.

OMO – Manipulate object – using hands or mouth to manipulate or inspect an object other than food (note the object being manipulated and how manipulated)
OSO – Sniff object – sniff object in enclosure (note the object)
OSA – Sniff air – smelling the air
U – Urinate
D – Defecate
OY- Yawn
OSW – Swinging – holding on to a branch or vine or toy and using it to swing body around (although not moving from point A to point B)
Other- Describe!

Appendix B

Annotated Bibliography

Altmann, J. (1974). Observational study of behavior: Sampling methods. *Behavior, 49,* 227-267.

This article provides an overview of the many different sampling methods available to the behavioral scientist. Altmann provides a description of seven sampling methods and the strengths and weaknesses of each. She describes Ad libitum, sociometric matrix completion, focal-animal, all occurances of some behaviors, sequence, one-zero, and instantaneous and scan sampling methods. Of these, I believe focal-animal and instantaneous/scan sampling methods will be the ones I use. Both provide good information about activity budgets, so before I have a more specific question it may be best to utilize these methodologies. Altmann makes some good observations and tips about designing an observational study. She suggests that before deciding on a sampling method, one should have a specific question in mind, and choose the method best suited to answering the question. The definitions of terms such as events vs. states are also explained.

Association of Zoos and Aquariums. (1998). *Constructing behavior profiles of zoo animals: Incorporating behavioral information into captive population management.* Washington, DC: Carlstead, K.

This is a report specifically for zoo workers that contains information on the importance of behavioral characteristics of animals in population management. The focus is on successful husbandry, but the premise is that behavior is important to consider. The paper includes information on constructing behavior profiles for individual animals in zoos. Their main goal was to integrate

standardized behavioral assessment techniques that could be used for comparisons across institutions. This manual provides step-by-step instruction in constructing and using behavior profiles in zoos. It will be very helpful for me when constructing my own ethogram. It will also help me when I contact other zoos. I will know what information might have been collected, and how keepers might react (or have reacted) when asked to fill out questionnaires. The author also included information on the reliability and validity of keeper ratings, which will also be useful. The author also includes a section on testing for statistical significance, which will also be helpful, since I have never tested for significance in this type of study. The reference list might also provide more sources that I have not yet considered.

Association of Zoos and Aquariums. (2007). *Old World Monkey Taxon Advisory Group Mixed Species Manual.* Houston, TX: Strange, D.

This is a really important source for any zoo putting together a mixed-taxa exhibit. It contains the general information about mixed-taxa exhibits, and it has a list, by animal, of mixed-taxa exhibits that exist or existed around the time that the manual was put together. With it you can see which primates have been housed together and whether they were successful. Although DeBrazza's have been housed with other primates, they ultimately have been removed in most situations. The pattern that animals in mixed-species exhibits are not breeding is also apparent in this document. This is a good source for finding other institutions with DeBrazza's in mixed-species exhibits. It is also important because it shows where the general ideas and zoo knowledge about mixed-taxa exhibits are right now.

Baker, A. J., Baker, A. M., & Thompson, K. V. (1996). Parental care in captive mammals. In D. G. Kleiman, M. E. Allen, K. V. Thompson, & S. Lumpkin (Eds.), *Wild mammals in captivity* (pp. 545-565). Chicago, IL: University of Chicago Press.

This chapter is very relevant for this project. It contains both relevant background information on the evolution of parental care (and why it is adaptive) as well as information on general patterns of parental care in mammals. There is a section on maternal care as well as alloparenting and paternal care. There are examples of non-human primate parenting patterns both in captivity and in the wild. The article also focuses on ways to facilitate parental care in a captive setting (where there is a higher likelihood of maladaptive parental behaviors). The chapter summarizes the research that has been done on minimizing stress on the mother and newly born infant in captive primate groups as well as comparing mother-rearing to hand-rearing new-borns. This article is particularly relevant for this project that is focusing on parental care in a group of captive primates. The patterns described in this article can be used to compare the behaviors observed in the DeBrazza's monkeys.

Bakeman, R., & Gottman, J. M. (1986). *Observing interaction: An introduction to sequential analysis.* New York, NY: Cambridge University Press.

This book provides in-depth instruction in sequential analysis of behavior. Depending on which sampling method I choose to use, this book will be more or less helpful. There are aspects of the book that can be used regardless, such as information on building a coding system and time sampling information. They even discuss the benefits of using pencils and paper to record samples (such as they are cheap, you never look down to realize all of your work has disappeared,

and they travel easily). If I decide to use a sequential analysis method this book will become much more important.

Box, H. O. (1984). *Primate behavior and social ecology.* New York, NY: Chapman and Hall.

This book covers a lot of important topics in primate behavior and social interactions. The author describes interspecies interactions as well as how things like predation affect behavior. She also describes how intra-species interactions are determined by ecology, and how ecology affects these behaviors. Social development is also discussed and the effects of captivity are considered. Specific environmental changes such as the birth of the infant are also considered, which is particularly important for this project. Parenting and caregiving are discussed in the context of both maternal and alloparental care. Male interaction with infants is included as well. This book provides a lot of important and relevant information for this project not only about parenting but about how ecology and the environment interact to affect behavior.

Brennan, E. J. (1985). De Brazza's monkeys (*Cercopithecus neglectus*) in Kenya: Census, distribution, and conservation. *American Journal of Primatology, 8,* 269-277.

This article appears to be one of the first censuses of the de Brazza's monkeys in Kenya. This census collected information on group size, age-sex composition, behavior, time and location. The researchers also described the forests and climate in which the de Brazza's were found. Most groups were found in riparian habitats, however most of these habitats are being cleared for farmland. This article can be used to provide more information about the natural history and behavior patterns of de Brazza's in the wild.

Byrne, R. W., Conning, A. M., & Young, J. (1983). Social relationships in a captive group of Diana monkeys (*Cercopithecus diana*). *Primates, 24,* 360-370.

This article explores how individuals in a group of captive Diana monkeys interact with infants. Diana monkeys are a closely related group to DeBrazzza's so the findings can be related to potential DeBrazza's behaviors. The group of monkeys was a single-male group with multiple females (and multiple infants). The authors found that infants do not groom and are most often groomed by their mother and the nulliparous female in the group. The same is mostly true for the juvenile (although with a little more grooming from the juvenile). Most grooming occurred between the females in the group. This article also clearly demonstrates the pattern of development of the infant and its increasing independence as it ages. The authors observed that other individuals in the group did interact with the infant, although the other group members showed more interest when the infant was just a few weeks old rather than when it had become more independent. This article is important because it is an example of a behavioral study that includes parenting observations of a group of closely related monkey to DeBrazza's. These findings might correlate to those of my project, and the methodology used in this article can be used to influence my methodology.

Clutton-Brock, T. H. (1991). *The evolution of parental care.* Princeton, NJ: Princeton University Press.

This book provides an overview of parental care across animal species. It not only covers mammals (and primates) but also ectotherms such as fish. It discusses why certain parental strategies have evolved as well as their adaptive significance. The author discusses costs and benefits associated with parental care, as well as how parents and offspring have different ideal levels of care and energy. He also describes when paternal care rather than maternal care might

evolve and why. It provides many explicit examples from the animal kingdom, which are very helpful in making connections between the theories of parental care and how they actually are expressed. This book is a great resource for understanding parental care and making comparisons across groups. In order to understand what makes primate parenting unique it is important to learn about parenting strategies in other species, and this book provides that information. Because this project includes a section on parenting in primates, this book is a very important reference.

Crockett, C. M. (1996). Data collection in the zoo setting, emphasizing behavior. In D. G. Kleiman, M. E. Allen, K. V. Thompson, & S. Lumpkin (Eds.), *Wild mammals in captivity* (pp. 545-565). Chicago, IL: University of Chicago Press.

This chapter takes the Altmann (1974) article and expands upon it to make it relevant for research done in a captive setting. As seminal as the Altmann (1974) article was, it was clearly written for field research. This article takes the important points and expands upon them using captive research examples and questions. The author takes the reader through the research process and describes considerations that should be made as well as important questions that can be answered by captive mammal research. This article will be vital to me for my methodology. The author describes different methods and protocols that can be used and the pros and cons of each. Effective ethograms are also described. Important words such as "event" and "state" are defined and the limitations to the research are discussed. Data analysis is also described and considerations such as effect size are mentioned. This is a very important chapter that anyone pursuing zoo research should read before determining their methodology and questions.

Estes, R. D. (1991). The behavior guide to African mammals: Including hoofed mammals, carnivores, primates. Los Angeles, CA: University of California Press.

This book has a lot of information on many different African mammals, including DeBrazza's monkeys. It provides an overview of the family Cercopithecidae, and some behavioral traits associated with them. It also breaks down the guenons and describes some of the traits that differentiate them. It provides comparative information and shows how these monkeys are all related. This is important, because very little work has been done on DeBrazza's monkeys, so a lot of the important literature must come from a closely related species, and this book shows how these animals are similar or different.

Fairbanks, L. A. (1993). What is a good mother? Adaptive variation in maternal behavior of primates. *Current Directions in Psychological Science, 2,* 179-183.

This is an important article for this project because it provides a clear overview of the research that has been done on maternal behavior in primates. The author describes why some of these behaviors may have evolved and some of the theories behind maternal behavior such as parental investment theory. Parental investment theory explains why a mother will stop investing as much in her current offspring in order to be able to provide for her next. The author also explains that mothers whose previous offspring died will invest more in current offspring. Other patterns of maternal behavior are also described in this article (such as the ways in which juvenile behavior and interactions change after its mother has a new infant). We can look for similar patterns in my project because there is a juvenile offspring and a new infant to the same mother. Also, the author was working with vervet monkeys, which is another closely related species of Old World monkeys to DeBrazza's. The article also explored alloparenting and

grandmothering, but because the monkeys at the MN Zoo are housed in a monogamous pair, some of the findings are less relevant to this project.

Fairbanks, L.A. (2003). Parenting. In D. Maestripieri (Ed.), *Primate Psychology* (pp. 144-170). Cambridge, MA: Harvard University Press.

This chapter is an important and comprehensive overview of much of the literature on parenting research in primates. The author describes ethological research (and its historical roots) and behavioral descriptions as well as patterns observed in primate parenting. Infant development and the ways in which it affects maternal behaviors are also discussed. The energetic costs of parenting are considered, and reference is made to observations made on wild populations of monkeys. This chapter also explains how a juvenile's relationship with its mother changes after the mother has a new infant. Many of these patterns of parenting behavior have been observed across primate species and therefore we can expect to observe similar patterns in the primates at the MN Zoo. This article also considers the role of fathers. The author explains the idea that because paternity is often uncertain, males rarely invest as much as females in raising offspring. The author of the article also points out that while patterns may become apparent across primate groups, there is a lot of individual variation across mothers and species. This chapter also considers how things like young or first-time mothers might interact with their offspring differently than more experienced primate mothers as well as how the dominance hierarchy affects maternal behaviors. This is a very important chapter for anyone to read who is going to study parenting in primates, and it describes many patterns that I will look for in my project.

Fleagle, J. G. (1988). *Primate adaptation and evolution.* San Diego, CA: Academic Press, Inc.

This book provides an overview of primate phylogeny and evolution. It describes both living and fossil primates as well as their habitats and activity patterns. It also goes into detail about the distinction between New World monkeys and Old World monkeys. It also describes primate adaptations such as diet and locomotor adaptations that have been used to differentiate between primate groups. This book provides good information about differentiating between primates, and it also provides background information on the primates that I am studying. The major focus of the book is on the fossil record and how that has influenced what we think about primate evolution. These parts of the book are less relevant to this study, but can be an important resource in the future.

Forster, S. & Cords, M. (2005). Socialization of infant blue monkeys (*Cercopithecus mitis stuhlmanni*): Allomaternal interactions and sex differences. *Behavior, 142,* 869-896.

This article describes a research project done on three habituated groups of blue monkeys that looked specifically at parenting behaviors and alloparenting. Blue monkeys are closely related to DeBrazza's monkeys, so some of the findings can be relevant to this project. The authors found that although there did seem to be differences between the patterns observed in each group, infants associated with other infants and large juvenile females more often than would be predicted by chance and less often than expected for non-maternal adult females. They also found that there was a lot of interest within the group in the new infant, and at about age 2-5 months the infant would often be carried by other females in the group. These and other patterns observed by the authors are important because they represent patterns in the wild of a closely related species to the study species

in my project. The connection between this article and my project will be difficult, however, because there are no other adult female DeBrazza's in the MN Zoo exhibit available to alloparent. However, the article does describe an effective methodology for studying parenting and alloparenting in this genus.

Hardy, D. F. (1996). Current research activities in zoos. In D. G. Kleiman, M. E. Allen, K. V. Thompson, & S. Lumpkin (Eds.), *Wild mammals in captivity* (pp. 531-536). Chicago, IL: University of Chicago Press.

This article explores the importance of zoo research as well as the history of research programs in zoos. Zoos provide the researcher with the unique opportunity of studying relatively uncommon animals while also knowing their life history. Zoo research started as taxonomic and anatomical descriptions, although very quickly environmental enrichment and conservation biology were also being studied. More recently zoo research has focused on reproductive biology, behavior, and genetics. *Zoo Biology* is a journal that was started in 1982 with the purpose of sharing Zoo research with other institutions. Other organizations have emerged with the purpose of sharing information and building working relationships between zoos and aquariums. This article will provide good background information about why this research is important.

Hosey, G., Melfi, V., & Pankhurst, S. (2009). *Zoo animals: Behavior management and welfare.* New York, NY: Oxford University Press.

This textbook provides a basic outline of many of the issues associated with zoo animal behavior, husbandry, and welfare. In particular, chapter 4 has a lot of information about how zoo animals respond to captivity and the zoo environment. It describes the research that has shown that quality, not quantity, is important when designing a zoo exhibit. Chapter 4 also describes how the social

environment in a captive setting is very important when considering the welfare of the animals, which is particularly important for the animals in this study that are in a unique social environment. The authors even describe some of the implications associated with having mixed-taxa exhibits. Chapter 14 of this book describes zoo research and some of the challenges associated with it. It also describes effective ways to collect data and describes research questions that could be asked in a zoo setting. The authors also describe some of the difficulties associated with data analysis and zoo research such as small sample sizes and lack of independence of variables. This is a good textbook resource, and it has many more interesting chapters that are more relevant from a husbandry management perspective than for this project.

Huntingford, F. (1984). *The study of animal behavior.* New York, NY: Chapman and Hall.

This book provides another overview of the study of animal behavior. It has a explanation of how to measure behavior. It goes into detail about how to correlate observations of behavior with the physiological mechanisms that might underlie them, but this is outside the scope of this study. The author also discusses how behaviors develop and why certain behaviors are significant. It also discusses phylogeny and behavior as well as genetic components of behavior. This book mostly contains information irrelevant to this study, or information that is covered by other sources that are more specifically related to observing behavior.

Hutchins, M., Thomas, P., & Asa, C. S. (1996). Pregnancy and paturation in captive mammals. In D. G. Kleiman, M. E. Allen, K. V. Thompson, & S. Lumpkin (Eds.), *Wild mammals in captivity* (pp. 468-495). Chicago, IL: University of Chicago Press.

This article describes in detail the physiology of pregnancy and parturition. It is particularly interesting how the article brings in information about how captivity affects these things as well as interbirth intervals, timing of birth etc. The most important sections of this chapter for this project were the sections describing interbirth intervals as well as the section on the behavioral signs of impending birth especially because the birth of the infant at the zoo was so unexpected. The other really relevant section of this chapter was about the ways in which conspecifics interact with the pregnant mother and the infant. Although examples of primates as well as other animals were used, much of what the article discussed was relevant for this project. This is an important chapter, and it contains applicable information about captive mammals and pregnancy and parturition.

Immelmann, K. (1980). *Introduction to Ethology.* (E. Klinghammer, Trans.). New York, NY: Plenum Press.

This book is a little outdated, but it does have some good information and definitions in terms of social behaviors. It has a lot of information about behavioral physiology and the influence of the nervous system, but I'm going to focus on the information it provides on fighting behavior and behavior of groups in chapter 8. The book contains a lot of information about underlying motivations for behavior, but I'm not sure any of it has been substantiated and it seems almost too anthropomorphic to assume any motivation behind behavior.

Jacobs, G. H., & Deegan, J. F. (1999). Uniformity of colour vision in Old World monkeys. *Proceedings from the Royal Society B: Biological Sciences of London, 266,* 2023-2028.

This article examines the possibility that the assumption that all Old World monkeys have trichromatic colour vision might be incorrect. This is possible because very few monkeys have been tested, and the hypothesis that trichromatic vision evolved to help frugivores might not be applicable to foliovores. They did find trichromatic vision in all the monkeys they tested including de Brazza's monkeys. This could have important implications for the use of color in enrichment and feeding of these monkeys.

Kleiman, D. G. (1992). Behavior research in zoos: Past, present, and future. *Zoo Biology, 11,* 301-312.

This article examines the history of zoo behavioral research and how this research has influenced management practices as well as influencing behavioral sciences. Zoos have large amounts of animal diversity within a very controlled setting. This makes them a great place for comparative studies as well as multi-generational studies. Zoos have also been used as locations for evolutionary research and ecological research. This article directly addresses the importance of behavioral research in zoos as well as makes comparisons about different types of zoo research. This article provides information about the history and future of behavioral research in zoos.

Lamb, M. E. & Goldberg, W. A. (1982). The father-child relationship: A synthesis of biological, evolutionary, and social perspectives. In L. W. Hofman, R. Gandelman, & H. R. Schifffman (Eds.), *Parenting: Its causes and Consequences* (pp. 55-73). Hillsdale, NJ: Lawrence Erlbaum Associates, Publishers.

This chapter explores paternal care in human males. It seeks to answer questions regarding the evolution of paternal care by investigating paternal care in non-human primates and other animals. It describes that paternal care develops when a lot of care is required in order to ensure that the young survive to grow and reproduce. Within primates, as you go further along the phylogeny (i.e. get closer to humans) more infant care is required. The authors explore both maternal and paternal care across species in order to describe some of the determinants of these patterns such as changing levels of hormones. This is an important article because there is potential for paternal care in the study group of DeBrazza's monkeys, and this chapter provides background information on the evolution of this behavior.

Lehner, P. N. (1979). *Handbook of ethological methods.* New York, NY: Garland STPM Press.

This book, more focused on field research, has information on developing an ethogram and general descriptions of behavior. It also provides information that will help me think about defining the question that I hope to answer (as well as developing hypotheses). It also has useful information about making a form with which to write down the behaviors I observe. Given my previous concern about this issue, this section is very helpful. It even includes different examples of different forms for different methodologies. It also goes through the different sampling methods that one might choose from, and describes them in detail. It also has a much more in-depth description of statistical methodologies that might

prove useful depending on how I design my study. The section on presenting results will also be helpful when writing up all that I have found.

Leutenegger, W. & Lubach, G. (1987). Sexual dimorphism, mating system, and effect of phylogeny in de Brazza's monkey (*Cercopithecus neglectus*). *American Journal of Primatology, 13,* 171-179.

Sexual dimorphism has generally been associated with polygyny in primates. However, groups of monogamous de Brazza's monkeys have been observed in Gabon. This article sought to explain this apparent inconsistency by looking at the evolutionary history of these monkeys. They also looked at things like patterns in growth and development, behavior, and social organization. It is good to know that monogamous groups have been observed because the group at the Zoo has been forced into a monogamous pairing. This article also provides a synthesis of some of the research done on de Brazza's monkeys' natural history and behavior patterns. Although the high sexual dimorphism and low polygyny do not follow normal patterns seen in other species, indirect evidence suggests that this is due to a historically higher level of polygyny.

Mallapur, A. (2005). Managing primates in zoos: Lessons from animal behaviour. *Current Science, 89,* 1214-1219.

This article summarizes two studies done exploring the behavior of non-human primates in zoos in India. They compare the behavior of captive primates with wild primates and compare how exhibits of differing complexity affect the behavior of the animals. They found that folivores fared much better than omnivores, and they hypothesized that this was the case because omnivores were not given their usual mixed diet, nor did the omnivores have environments sufficient to provide high levels of activity and enrichment. They concluded that

environmental enrichment is important, and they also found that even in more enriched environments negative behaviors might develop depending on an animal's early rearing history. This article is a direct example of the importance of environmental enrichment as well as an example of research done with non-human primates in captive (often mixed-species) environments.

Manaster, B. J. (1979). Locomotor adaptations within the *Cercopithecus* genus: A multivariate approach. *American Journal of Physical Anthropology, 50,* 169-182.

This article examined how different morphological characteristics of *Cercopithecus* primates were related to their patterns of locomotion. They looked at subtle differences and compared them to each species' habitats and the differences in movement required to thrive in those habitats. Some of this information can be used to talk about de Brazza's monkeys habitats and their locomotor habits.

Maple, T. L. (2007). Toward a science of welfare for animals in the zoo. *Journal of Applied Animal Welfare Science, 10,* 63-70.

This article contains a lot of information about the current trends in zoo animal welfare. It uses nonhuman primates as an example that should be emulated for other species. It provides an overview of important innovations in keeping primates, such as the use of operant conditioning, and the importance of vertical space in exhibits. I also like this article because it concludes that zoos should employ doctoral-level animal behaviorists to maintain good zoo practices. Its reference list also provides a long list of possible sources if I decide to pursue the idea of using enrichment in my project.

Martin, P., & Bateson, P. (1986). *Measuring behavior: An introductory guide.* New York, NY: Cambridge University Press.

This is a great book. It has a lot of information about designing a behavioral observation study. It provides sections on choosing categories and defining them as well as what to measure in terms of these categories. It also provides information about making sure that the method I choose to use is reliable and/or valid. Along the same lines it provides information on statistics and data analysis, which will be very helpful. The last section includes information on miscellaneous issues that I know in the future will be problems that I will appreciate having answers to. This book will be integral when I'm designing my protocols and ethogram.

Montanga, W. (1976). *Nonhuman primates in biomedical research.* Minneapolis: University of Minnesota Press.

This book has a chapter about the natural history of primates that provides a great overview of the evolution and patterns of primates. I used it as a starting point in understanding where de Brazza's fit into the larger picture of primates in general. The chapter contains ecological information as well as phylogenetic and behavioral information. It talks about the different primate families and discusses each one at length. It was in this chapter that I realized that Colobus and de Brazza's monkeys belong to the same family Cercopithecidae, but they are separated into different subfamilies.

Mugambi, K. G., Butynski, T. M., Suleman, M. A., & Ottichilo, W. (1997). The vanishing de Brazza's monkey (*Cercopithecus negleglectus* Schlegel) in Kenya. *International Journal of Primatology, 18,* 995-1004.

This article contains a lot of information about the de Brazza's monkeys' range across Africa. The authors conducted a census of a forest in Kenya. They talked to local villagers to find out where de Brazza's had been seen, and they conducted their own "reconnaissance" before beginning their actual census. When they found a group of de Brazza's they counted them and determined their altitude, location, height above ground, and the distance the monkeys were from the river and the observers. This study provides more information about de Brazza's habitat and their natural history.

Oswald, M., & Lockard, J. S. (1980). Ethogram of the de Brazza's guenon (*Cercopitecus neglectus)* in captivity. *Applied Animal Ethology, 6,* 285-296.

This article has some good information about de Brazza's in its introduction (natural history, family groupings, habitat etc.) It also provides an example of an ethogram that was actually used by the researchers to make activity budgets for de Brazza's monkeys living in captivity. Although these monkeys lived in a larger group than the one at the MN Zoo, this ethogram will be helpful in deciding which behaviors are important to note. Their ethogram described locomotion modes, affiliative behavior, agonistic behavior, ingestion behavior, habitat utilization, and social structure. These monkeys were not housed with any other species so the social behaviors I observe may be more complex, and I might have to account for more behaviors than the author's did.

Pereira, M. E., & Fairbanks, L. A. (Eds.). (1993). *Juvenile primates: Life history, development and behavior.* New York, NY: Oxford University Press.

This book contains many chapters that will be useful to this project if I focus on the juvenile primate in this group. There are articles that cover juvenility in animals and how and why certain characteristics evolved. The ability to observe a juvenile in a captive setting allows the observer to see many behaviors that are often hidden in the wild. I imagine that my project will verify many of the behaviors and patterns described in chapters 1-5. I also believe that the chapters on Vervet monkeys might be helpful. Vervet monkeys are in the same family as de Brazza's monkeys, so some similar patterns might exist.

Rowell, T. E., & Richards, S. M. (1979). Reproductive strategies of some African monkeys. *Journal of Mammalogy, 60,* 58-69.

This article looked at seven different African monkey species that were all living at the Institute of African Primatology in Kenya. All the species were housed in breeding groups. The species were compared to see whether reproductive strategies and cycles were due to species differences, or due to things like climate and food availability. Many different strategies had been observed in the wild, and the researchers wanted to find out the source of these differences. This article contains a lot of information about the breeding cycle of de Brazza's monkeys. It has information about their gestation and birth intervals (5.5-6 months and 20 months respectively). An interesting aspect of this study was that the monkeys were housed in individual groups, but near other groups so synchrony of births was possible. There is also information about longevity and its relationship to breeding.

Silverberg, J., & Gray, J. P. (Eds.) (1992). *Aggression and peacefulness in humans and other primates.* New York, NY: Oxford University Press.

This book is an edited work that contains chapters discussing aggression and affiliation in primates. The first chapter considers the possibilities of both aggression and peacefulness in primate societies and why one might arise. It discusses dominance and how it affects intergroup interactions. It also defines useful terminology for discussing aggression (rather than 'violence'). The book also contains a chapter on Cercopithecine societies, however, this chapter does not include information on de Brazza's monkeys. De Brazza's are relatively unique even within this group, so the information about other species and their relative aggression might not be as useful.

Smith, H. J. (2005). Parenting for primates. Cambridge, MA: Harvard University Press.

This book is a great overview of the research that has been done on parenting in primates. It includes research on maternal care, paternal care, alloparenting, as well as development of the infant. It also covers research on solo parenting (only the mother cares for the offspring) as well as research on those groups that do have both parents care for offspring. For this project the most important chapters were those on alloparenting and paternal care because this book synthesized most of the research out there as well as pointed me towards articles and researchers doing the pertinent studies. There is not a lot of research on the subject, so having it all together in one place was very helpful. I learned about the theories related to how males care for offspring as well as how mothers interact with their previous offspring after the birth of a new infant all in the same book. The author included examples of closely related species to DeBrazza's monkeys as well as research on apes and New World monkeys. The book was also written fairly recently, so the research cited was up to date.

Thomas, W. D. & Maruska, E. J. (1996). Mixed species exhibits with mammals. In D. G. Kleiman, M. E. Allen, K. V. Thompson, & S. Lumpkin (Eds.), *Wild mammals in captivity* (pp. 204-211). Chicago, IL: University of Chicago Press.

This chapter describes the research that has been done on mixed-species exhibits with mammals. It describes the history of mixed-species exhibits as well as important considerations that should be made when putting mammals together. The authors describe special considerations that should be made for primates. The authors make recommendations for the design of the mixed-taxa exhibit and describe how effective species introductions can be made. The authors also explain that while there might not be overt aggression between two primate groups, one group might experience high levels of stress due to the mixed nature of the exhibit. This chapter provides a list of mammals that have been housed together and it includes some primate species. This is an important reference for zoos considering mixed-taxa exhibits as well as for this project because it describes the considerations that should be made with these exhibit types.

Wahome, J. M., Rowell, T. E., & Tsingalia, H. M. (1993). The natural history of de Brazza's monkey in Kenya. *International Journal of Primatology, 14,* 445-466.

This article is a report on a study done in Kenya observing the behavior of three polygynous groups of de Brazza's monkeys. It reports on home range size as well as use of their space (such as how much time they spent high in the trees etc.) This study reports that these monkeys live in similar habitats to black and white Colobus monkeys, and while generally the de Brazza's were aggressive towards other monkeys they were observed sharing the food trees with the Colobus. This article has great information about group composition, habitat description and use, their feeding patterns, and social behaviors. The authors also make comparisons

between these groups observed and other groups that had been observed previously (some of the articles I have not been able to find). This article contains a lot of information about the behavior of these monkeys in the wild that could inform what I look for with this project, and might inform how I look at the exhibit setup.

Waters, E. & Deane, K. E. (1982). Infant-mother attachment: Theories, models, recent data and some tasks for comparative developmental analysis. In L. W. Hofman, R. Gandelman, & H. R. Schifffman (Eds.), *Parenting: Its causes and Consequences* (pp. 19-54). Hillsdale, NJ: Lawrence Erlbaum Associates, Publishers.

This chapter explored the idea of infant-mother attachment in both humans and non-human primates. Attachment is important in humans in primates not only because if a mother is attached to her infant, she is more likely to protect it from predators etc., but also attachment is also associated with social and cognitive development. This chapter also describes the different theories that exist about the development of attachment. In doing so it explores research that has been done on neonatal and infant behavior that is related to infant-mother attachment as well as the effects of environmental stressors and peer relations. This article is important because it describes some of the research that has been done on parenting behaviors in primates, and how attachment plays a role in these behaviors.

Wiesenfeld, A. R. & Malatesta, C. Z. (1982). Infant distress: Variables affecting responses of caregivers and others. In L. W. Hofman, R. Gandelman, & H. R. Schifffman (Eds.), *Parenting: Its causes and Consequences* (pp. 123-139). Hillsdale, NJ: Lawrence Erlbaum Associates, Publishers.

This chapter explores how infant behavior engages parents and encourages care in primates (including humans). The authors propose that attachment may have evolved from a sensitivity of mothers to infant signaling. This chapter looks specifically at how caregiver responses vary with infant distress calls, and looks at the underlying mechanisms determining the level of caregiver sensitivity. Although this chapter is most relevant to humans, because it explores how attachment and maternal sensitivity to infant distress evolved, it is relevant for non-human primates. The authors show interesting variations with responses to pain cries versus anger cries as well as differences in responses to ones' own infant and a strange infant. Although this article is very interesting, it contains only a little relevant information for this project.

Wojclechowski, S. (2004). Introducing a fourth primate species to an established mixed-species exhibit of African monkeys. *Zoo Biology, 23,* 95-108.

This article describes how the keepers at the Brookfield Zoo introduced a fourth primate species (red-capped mangabeys) to an exhibit containing black and white Colobus, mandrills, and sooty mangabeys. This is an important article because it describes the interspecific interactions observed when multiple Old World primates were housed together. A major difference between the interactions in this article and my project is that none of the primates were breeding. This article contains important background information, not just for me and my project, but also for zoos considering mixed-taxa exhibits. The author shows that it is possible to house multiple primate species together, even two species in the same

genus. The author also describes protocols to safely introduce the species to each other to avoid aggression. While this project is not focused on how to introduce primate species to each other, it is important because it raises the issues that should be considered when working with a mixed taxa primate exhibit.

Wolfheim, J. H. (1983). *Primates of the world: Distribution, abundance, and conservation.* (409-412) Seattle: University of Washington Press.

This book contains an entire section on de Brazza's monkeys. It includes their geographic range, their abundance and density, their habitat, factors that affect their populations (such as habitat alteration, human predation, pest control, and collection). It also includes information on conservation action that is occurring in Africa. This is a good source of background information on this species and their habitat and natural history.

Young, R. J. (1998). Behavioral studies of guenons at Edinburgh Zoo. *International Zoo Yearbook, 36,* 49-56.

This article summarizes the research that has been done on the guenons (genus *Cercopithecus*) at the Edinburgh Zoo. It is particularly interesting because of the comparisons made across species on social behaviors and feeding and foraging behaviors. The main study species in this article is not the DeBrazza's monkey, but because all of the species described in the article are closely related, the studies results and methodologies are important for this project. The author found differences in social structure and behavior between the species, which reiterates how important it is to study each individual species on its own. The information on feeding and foraging was also interesting because the researchers found that certain ways of distributing food (i.e. spreading it around) resulted in less aggression in all of the monkeys studied. The section on mixed-species exhibits

was also very relevant for this project because it described a successful introduction of Diana monkeys into a gorilla enclosure. It was particularly salient because there was an infant Diana monkey in the enclosure with the gorillas. This is one of the few examples that I have come across that describes a successful introduction of breeding primates into an enclosure with other primates. This article also contains a lot of important information on the genus *Cercopithecus* and what separates it from other groups of monkeys.

Zuberbuhler, K. (2007). Predation and primate cognitive evolution. In S. L. Gursky & K. A. I. Nekaris (Eds.), *Primate Anti-predator Strategies* (pp. 3-26). Chicago: Springer Science.

This article examines how predation has played a role in the evolution of primates. It mentions specifically that most African primates associate with other primate groups, however this is untrue of de Brazza's monkeys. This is interesting because it is hypothesized that this behavior evolved as an anti-predator strategy. The article goes through a number of different predators and how primates reacted to them. Although it was an interesting article, it may not provide a lot of information to this study because there shouldn't be any predators at the Zoo. However some behaviors might be noted that are distinctly reactions to threat, and in that situation this article will be good to refer back to.