ENVIRONMENTAL ENRICHMENT FOR

GUMMIVOROUS PRIMATES

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ENVIRONMENTAL ENRICHMENT FOR

GUMMIVOROUS PRIMATES

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ABSTRACT

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Physical anthropologists that study the feeding behavior of wild primates report that many haplorhine and strepsirhine species consume the gum exuded from trees. These gum feeding primates include, but are not limited to, some of the Lemuridae, Galagidae, Callitrichinae, and Cercopithecinae. Although gum plays varying degrees of importance in their diets, at least one species from each of these families and subfamilies is a gum specialist. Despite the prevalence of gum in the wild diets of these animals, few data exist concerning gum feeding in captivity. This study evaluates whether or not the knowledge gained from wild studies is applied in captive environments.

Data were collected from 46 zoos in twelve countries via a web-based survey, with additional visits to both the Phoenix and Houston zoos for follow-up data collection. The majority of the responding zoos provide gum-based enrichment to marmosets (*Callimico*, *Callithrix*, and *Cebuella*- 83%), but only half provide gum to tamarins (*Leontopithecus* and *Saguinus*- 50%) and galagos (*Galago* and *Otolemur*- 50%). No zoos report feeding gum to baboons (*Papio* spp.), vervet monkeys (*Chlorocebus aethiops*), or patas monkeys (*Erythrocebus patas*).

Since environmental enrichment that stimulates naturalistic behavior promotes the psychological wellbeing of animals, gum feeding is likely to be important to the welfare of captive gummivores. This study shows that the needs of captive cercopithecines are not being met, particularly in the case of the patas monkey, an obligate gummivore. Practical application of ecological data in captive contexts is just one way physical anthropologists can contribute to the conservation and welfare of some of our closest living relatives.

CHAPTER I

INTRODUCTION

In the wild, many haplorhine and strepsirhine species consume the gums exuded from trees. These gum-feeding primates include, but are not limited to, some of the Lemuridae, Galagidae, Callitrichinae, and Cercopithecinae. Although gums play varying degrees of importance in their diets, at least one species from each of these families and subfamilies is a gum specialist. Despite the prevalence of gum in the wild diets of these animals, gum is not typically fed in captivity (Crissey et al. 2003). Here, I aim to evaluate the current state of captive gummivore enrichment, and to identify techniques and devices used in zoos across the world.

Environmental enrichment is an approach that seeks to provide for the psychological and physiological needs of captive animals (Kreger et al. 1998; Mellen & MacPhee 2001; Shepherdson 1998). Researchers have long realized that specific social and environmental stimuli are needed for normal primate development (Andrews & Rosenblum1994; Cross & Harlow 1965; Harlow et al. 1965; Harlow & Harlow 1962; Lewis et al. 2000; Sanchez et al. 1998; Shively et al. 1989; Shepherdson 1998; Suomi 1997). Enrichment programs attempt to provide opportunities for animals to engage in species-typical behaviors. Indeed, encouragement of species-typical behaviors is frequently cited as the primary goal of environmental enrichment (Kreger et al. 1998;

Lindburg 1998; May & Lyles 1987; Mellen & MacPhee 2001; Poole 1998; Seidensticker & Forthman 1998; Shepherdson 1998; Young 2003). Another commonly cited goal of captive enrichment is decreasing the amount of time spent in abnormal behaviors or inactivity (Kreger et al. 1998; Lindburg 1998; Mellen & MacPhee 2001; Young 2003). Elimination of abnormal or stereotypic behaviors is desirable because these types of behaviors can cause physiological or psychological stress (Kreger et al. 1998).

An important issue to address is how primate caretakers or researchers judge the psychological wellbeing of animals. Engaging in species-typical behaviors is often considered a marker for good mental health (Buchanan-Smith 1994; Kulpa-Eddy 2005; Shepherdson 1998; Taylor 2002), as is the lack of abnormal or stereotypic behaviors (Crockett 1998; Poole 1998). Poole (1998) suggests that whether or not an individual is busy (i.e. displays a wide repertoire of behaviors) and whether or not an individual is confident (i.e. moves around without fearfulness) are both good indicators of psychological wellbeing. In other words, a busy and confident animal is a happy animal. Crockett (1998) adds to this list of markers appetite as well as levels of cortisol in the urine or blood, which can indicate stress. Environmental enrichment is a useful way to address mental health because it helps to encourage desirable behaviors and discourage undesirable ones.

Environmental enrichment can also contribute greatly to meeting the four primary goals of zoos: conservation, education, recreation, and research (Kreger et al. 1998; Seidensticker & Forthman 1998; Shepherdson 1998). Encouraging species-typical behaviors is vital to each of these goals. Zoos help the conservation effort in several ways, such as readying animals for reintroduction into the wild, serving as rescue

facilities, and preserving species diversity. One important role zoos play in conservation is in educating the public about species diversity. As Markowitz and Aday (1998: 56) eloquently state: “Empowered animals serve as emissaries for their species by conveying to people the beauty of animal diversity.” In this way the goals of education and conservation are inextricably bound. When captive animals exhibit species-typical behaviors, the level of education provided certainly increases, and in turn so does visitor sympathy for the conservation effort (Markowitz & Aday 1998; Shepherdson 1998). Recreation, the third goal of zoos, is similarly influenced. Animals that actively engage in a diverse array of species-typical behaviors are undeniably more fun and interesting to watch (Morgan et al. 1998). Finally, providing opportunities for animals to behave naturalistically, thereby promoting psychological wellbeing, arguably leads to higher quality research. Atypical behavior and the associated physiological stress can lead to unwanted variation in experimental design, jeopardizing the validity of results (Kreger et al. 1998; Vitale & Manciocco 2004).

Dietary enrichment offers a perfect venue for encouraging species-typical behaviors. For wild primates, food procurement activities are a large part of daily life. Under natural conditions, diets usually vary daily, or at least seasonally; thus, dietary enrichment seeks to vary the timing, frequency, type, quality, and quantity of the captive diet (Baer 1998). Complexity of foraging is another necessary consideration for animals that, in the wild, depend on a wide variety of foods with different procurement and handling techniques (Poole 1998). It is worth noting, however, that care should be taken to ensure that dominant individuals do not limit access by others to preferred enrichment foods, which can lead to malnutrition and/or obesity (Baer 1998).

While environmental enrichment programs endeavor to encourage naturalistic behaviors, it is important to note that no amount of ingenuity can completely recreate the natural habitat (Kreger et al. 1998). Natural behavior should serve as a guide for enrichment design, but should not be the sole guiding principle (Mellen & MacPhee 2001). Not all behaviors can or should be encouraged in public zoo environments, if only because zoo visitors would not tolerate a totally natural zoo, with animals dying of disease and gorily consuming each other on a regular basis (Markowitz & Aday 1998). So there is a trade-off in zoos between providing natural environments for the animals and providing visitor entertainment. Despite this issue, zoos can still provide a variety of opportunities for animals to engage in species-typical behaviors, thereby supporting psychological wellbeing.

To assess zoo enrichment programs for primate gummivores, I conducted an international survey about enrichment techniques that simulate gum feeding behavior. These types of enrichment have the potential to play an important role in captive environments (Buchanan-Smith 1994). Primate gummivores possess a wide range of anatomical and behavioral adaptations for gum feeding, as do non-primate gummivores not discussed here, such as sugar gliders *(Petaurus breuiceps),* Leadbeater's possum *(Gymnobelideus leadbeateri*), and many insects (Nash 1986). In the following section I describe eleven genera of gum feeding primates: *Euoticus, Galago, Otolemur, Cebuella, Callimico, Callithrix, Leontopithecus, Saguinus, Erythrocebus, Chlorocebus,* and *Papio*.

Galagos (*Euoticus, Galago,* and *Otolemur*)

Galagos are nocturnal and weigh from 450 – 1500 gm (Nash 1986). The needle-clawed bushbaby (*Euoticus elegantulus*), the lesser bushbaby (*Galago senegalensis*), and

the thick-tailed bushbaby/greater galago (*Otolemur crassicaudatus*) are obligate gummivores (Nash 1986; Nash & Whitten 1989). *E. elegantulus* specializes on members of the thorn-tree family (Mimosaceae), and *G. senegalensis* and *O. crassicaudatus* particularly like the *Acacia* varieties of this family (Nash 1986). *E. elegantulus* uses gum consistently year round, but some galagos increase their consumption of gum during the winter, perhaps because invertebrates, another important food of galagos, are less available during that season.

G. senegalensis and *E. elegantulus* have dental combs that can be used to pierce globs of gum. The larvae of wood-boring insects also stimulate production of the gum (Garber 1987; Nash 1986). *E. elegantulus*' dental comb is especially large, and this species also has a caniniform first upper premolar that is possibly used for gouging, although this behavior has never been observed (Nash 2008, personal communication; Nash 1986; Vinyard et al. 2003). However, no gouging behavior has actually been confirmed for galagos; the anterior dentition does not appear sturdy enough (Nash 1986). *E. elegantulus* has keeled and pointed nails, but no other nail modifications related to gum feeding are present in other galagos. *G. crassicaudatus* prefers to hang underneath trees when feeding, using horizontal and angled supports, while *G. senegalensis* prefers vertical trunks.

Galagos have caecums and colons with expansion to allow for fermentation, similar to that seen in folivores, though less extreme (Caton et al. 2000; Chivers & Hladik 1980; Nash 1986). Efficiently extracting nutrients from leaves is difficult because leaves have high concentrations of digestion inhibitors (e.g. tannins), protein, minerals, and fiber (Garber 1987). For this reason folivores tend to have expanded caecums and colons for

microbial fermentation. Similarly, because gums are made of complex polysaccharides, digestion is assisted by microbial fermentation in the hindgut (Caton et al. 2000; Nash 1986; Nash & Whitten 1989). Nash (1986) reports that when on a diet that includes gum, *G. senegalensis braccatus* shows marked slowing of transit time, suggesting fermentation. Caton et al. (2000) updates this work, showing that the caecum, proximal colon, and ansa coli in *G. moholi* are adapted for mixing and retaining digesta for microbial fermentation. It seems the galago digestive system is adapted for fermentation of gums. With the indisputable importance of gum in the diets of these species, gum should play a primary role in environmental enrichment.

Marmosets (*Cebuella, Callimico,* and *Callithrix*)

Marmosets are diurnal and among the smallest primates. Pygmy marmosets, *Cebuella pygmaea*, weigh from 100 – 140 gm, and *Callithrix* spp. from 300 – 430 gm (Nash 1986). Pygmy marmosets are obligate gummivores and spend approximately 75% of their feeding time consuming gum (Nash 1986; Power & Oftedal 1996; Yepez et al. 2005). They eat gum consistently year round (Nash 1986) and tend to feed on gum during two daily peaks: one in the early morning and one in the late afternoon (Yepez et al. 2005). Many species of the genus *Callithrix* also dedicate a large portion of their diet to gum, such as the buffy-headed marmoset (*C. flaviceps*), a predominant gum-eater (Ferrari 1991). It is estimated that the common marmoset (*C. jacchus*) and the black tufted-eared marmoset (*C. penicillata*) devote between 20 and 70% of their annual feeding time to exudates, depending on the season (Power & Oftedal 1996; Nash 1986), although other species (e.g., *C. humeralifer* and *C. aurita*) probably consume far less. Goeldi's monkeys (*Callimico goeldi*) are reported to devote 3% of their feeding time to exudates in the wet

season and 20% in the dry season (Porter et al. 2007; Porter et al. 2009). *Cebuella* and *Callithrix* consume gum from a wide variety of trees, preferring those from the mango family (Anacardiaceae), the bush-willow family (Combretaceae), and the thorn-tree family (Nash 1986; Yepez et al. 2005). A group of marmosets may have one gum-producing tree as the focus of its range, particularly in *Cebuella* and *C. penicillata* (Nash 1986). All species of marmosets gouge trees (McGrew et al. 1986; Nash 1986) and some maintain holes for many years without seriously damaging the tree (Ferrari 1991).

Other foods eaten by *Cebuella* include plant reproductive parts and insects (Nash 1986; Yepez et al. 2005). Fruit eating is rare and negligible in this genus (Yepez et al. 2005). *Callithrix* spp. also eat plant reproductive parts and insects, but with a heavier importance on plants than in *Cebuella* (Nash 1986).

All callitrichids possess claw-like nails called “tegulae,” which are possible adaptations for exudate feeding (Caton 1996; Garber 1987; Garber 1992; Garber & Leigh 2001; Nash 1986). Marmosets use their nails to cling to large, vertical trunks of trees while feeding on exudates (Garber 1987; Garber 1992; Garber & Leigh 2001). Marmoset dentition may also represent an adaptation specific to gummivory (Nash 1986; Vinyard et al. 2003). The anterior dentition is short-tusked and lacks enamel on the lingual incisor surfaces (McGrew et al. 1986; Nash 1986). Indeed, in *Callithrix* the degree of procumbency of the incisors and the buttressing of the mandibular symphysis both appear related to the degree of gummivory (Nash 1986). Similar to bushbabies, *Cebuella* and *C. jacchus* appear to be caecum fermenters (Caton et al. 1996; Power & Oftedal 1996).

All this is strong evidence that marmosets possess a number of adaptations specific to gummivory. It is clear that addition of gum to the captive diet, especially in

the case of *Cebuella*, should be an essential component of enrichment programs. Marmosets are among the most commonly housed primates in zoos and research facilities, judging from my extensive foray into examining zoo websites to find potential survey participants. In captivity, *C. jacchus* frequently gouge holes in wooden cage furnishings, despite never being rewarded for doing so (McGrew et al. 1986).

Tamarins (*Leontopithecus* and *Saguinus*)

Tamarins average 300 – 700 gm in weight, and they are diurnal (Nash 1986). All species of *Saguinus* eat gums, although its importance in the diet varies greatly by species and by location (Heymann & Smith 1999; Nash 1986; Power & Oftedal 1996). Saddleback tamarins (*S. fuscicollis*) seem to eat the most gum; Power and Oftedal (1996) report an annual average of 5 – 58% of feeding time spent on gum. Heymann and Smith (1999) estimate an average of 7.3% for *S. fuscicollis* in northeastern Peruvian Amazonia, and 2.3 – 5.5% for sympatric moustached tamarins (*S. mystax*). For some species, such as cotton-top tamarins (*S. oedipus*) and members of the genus *Leontopithecus* (lion tamarins), gum may make up less than 5% of the diet (Power & Oftedal 1996). However, there are conflicting reports for *Leontopithecus*. Raboy and Dietz (2004) write that gum feeding in the golden-headed lion tamarin (*L. chrysomelas*) is negligible, although these tamarins are occasionally observed eating gum from holes gouged by sympatric Wied's marmosets (*Callithrix kuhli*). On the other hand, the black lion tamarin (*L. chrysopygus*) eats up to 55% gum, during the dry season (Passos 1999). Indeed, gum feeding in tamarins is often seasonal; this may be correlated with decreased fruit availability during the dry season (Nash 1986; Power & Oftedal 1996).

Saguinus spp. visit a wide variety of gum producing trees (Nash 1986). Other foods in the diet of *Saguinus* spp. include plant reproductive parts, insects, and nectar, with varying degrees of importance (Nash 1986). For *Leontopithecus*, primary components of the diet are ripe fruit, nectar, insects, and small vertebrates such as frogs, lizards, and small snakes (Raboy & Dietz 2004).

Although tamarins do not gouge holes, some species use holes gouged by marmosets (Nash 1986; Raboy & Dietz 2004). Other species, such as *S. mystax*, do not use marmoset holes because they rarely descend to low enough levels (Nash 1986). Trees also produce exudates in response to natural damage to the bark or to the activity of wood-boring insects (Garber 1987). Tamarins, unlike marmosets, have long-tusked dentition (Nash 1986; Crissey et al. 1998), but both marmosets and tamarins have tegulae in common (Nash 1986). Tamarins use their long fingers and claw-like nails for extractive foraging (Rapaport 1998).

Tamarins do not possess specializations of the digestive system for gum feeding, but Heymann and Smith (1999) observe a temporal preference for feeding on gum in the late afternoon. They hypothesize that feeding in the late afternoon allows for an increased amount of time for digestion. As tamarins do not defecate during the night, gum probably is not expelled after a short transit time.

Tamarins do not seem to be obligate gummivores, but addition of gum to the captive diet can nonetheless improve quality of life by encouraging species-appropriate behaviors. Variety in diet and promotion of foraging behaviors seen in the wild are vital to the wellbeing of captive primates (Buchanan-Smith 1994).

Patas Monkeys (*Erythrocebus*)

The patas monkey (*Erythrocebus patas*) is by far the largest primate gum specialist, and is the only catarrhine that shows a degree of specialization on gum (Nash 1986). Adult female patas monkeys weigh about 4 – 7.5 kg, and adult males about 7.5 – 13 kg (Isbell 1998). Patas monkeys are diurnal and spend about 20% of their active time feeding on gum (Isbell 1998; Nash 1986). In Laikipia, Kenya, 83% of the diet comes from products of the single species *Acacia drepanolobium* (Isbell 1998), the whistling thorn tree. In other areas patas monkeys eat gum and other products from a variety of *Acacia* species (Nakagawa 2000; Nash 1986). Gum is eaten year round, with increased importance during the dry season (Isbell & Young 2007; Nakagawa 2000; Nash 1986). Patas monkeys show no signs of nutritional stress during droughts, and even in the driest years reproductive rates do not appear affected (Isbell & Young 2007).

Gum and arthropods, such as ants (e.g., *Tetraponera* and *Crematogaster*), make up an estimated 40 – 50% of the patas monkey diet (Isbell 1998; Isbell & Young 2007; Nash 1986). Patas monkeys also eat young and mature swollen thorns of *Acacia*, flowers, seeds, pods, and mushrooms (Isbell 1998; Isbell & Young 2007).

For cercopithecines, patas monkeys have the longest legs relative to body size and can run up to 55 km/hr (Isbell 1998). They typically feed from the ground, frequently standing bipedally (Nash 1986). Patas monkeys travel an average of 3800 – 4200 m per day, and spend much of their time moving to find small, quickly eaten, and widely dispersed foods (Isbell 1998). Hall (1965) describes patas monkeys in Uganda as feeding at a steady walk. The patas monkey is quite unusual in its ability to subsist on a diet of gum and arthropods, as it weighs four times more than the next largest primate

gummivore or insectivore. Isbell (1998) argues that patas monkeys are able to sustain themselves on this diet, despite their relatively large body size, due to the abundance of gum and arthropods in their environment. Patas monkeys show no specializations for gum feeding in the nails or digestive system (Isbell 1998; Nash 1986), which suggests that gummivory may be a relatively recent adaptation; similarly, their dentition is not specialized, but damage to the incisors is consistent with gnawing and scraping (Nash 1986). Patas monkeys anchor the jaw against gum substrate using the lower incisors and scrape gum using the upper incisors.

As gum makes up one of the largest components of the patas monkey's wild diet, including gum in the captive diet should be a staple of patas monkey care. For such active primates as these, adequate enrichment is essential.

Vervet monkeys (*Chlorocebus spp.*)

Vervet monkeys (*Chlorocebus* spp.) are diurnal and weigh 3.8 – 5 kg (Nash 1986). Like patas monkeys, vervet monkeys mostly eat the gum of *Acacia* trees (Isbell et al. 1998; Nash 1986; Wrangham & Waterman 1981). In some areas gum makes up about 15 – 20% of the diet year round (Nash 1986). However some populations of vervet monkeys do not eat any gum, such as in Kala Moloue, Cameroon (Nakagawa 2000). Even in areas where vervet monkeys do not eat gum, products from *Acacia* trees are readily consumed, including fruits, seeds, flowers, and foliage (Isbell et al. 1998; Nakagawa 2000; Nash 1986; Wrangham & Waterman 1981). In Kala Moloue, a main component of the diet is grasshoppers (Nakagawa 2000).

Vervet monkeys possess no specializations for gum feeding of the nails, dentition, or digestive system (Nash 1986; Bruorton et al. 1991). Bruorton et al. find that the

caecum and colon of vervet monkeys are much smaller than in folivorous samango monkeys (*Cercopithecus mitis*). Vervet monkeys also have lower concentrations of volatile fatty acids for fermentation than folivorous monkeys, so vervet monkeys do not seem to possess adaptations for improving efficiency of gum digestion. It is clear that gum does not usually make up an essential component of the vervet monkey diet. Nevertheless, enrichment that encourages gum foraging behavior can still be utilized to encourage naturalistic behaviors, enhancing the psychological wellbeing of captive vervet monkeys.

Baboons (*Papio*)

Among baboons, yellow baboons (*Papio cynocephalus*) are the primary gum consumers (Altmann 1998; Nash 1986; Paterson 2006). All baboons are diurnal and, broadly speaking, around the same size. Yellow baboons weigh from 11 – 30 kg (Nash 1986), making them the largest primate species to consume a substantial amount of gum in the wild. Yellow baboons spend an annual average of 7% – 20% of feeding time consuming gum (Altmann 1998; Nash 1986; Stacey 1986). Yellow baboons of the Sonso troop in Uganda also reportedly consume a substantial amount of gum, although the percentage is not specified (Paterson 2006). Gum is an important year round food source, especially for weaning baboons in Amboseli (Altmann 1998; Nash 1986). Yellow baboons consume gum from a variety of *Acacia* species, the favorite of which is the fever tree, *A. xanophloea* (Altmann 1998; Nash 1986). The most frequently eaten food of yellow baboons is corms, although they eat foliage, plant reproductive parts, bark, insects, and an occasional domestic chicken as well (Nash 1986; Paterson 2006).

Few reports exist for gum feeding in other species of baboons. Hamadryas baboons (*P. hamadryas*) in central Ethiopia reportedly subsist largely on the flowers, leaves, and seeds of *Acacia* spp., particularly *A. senegal* (Swedell 2002; Swedell et al. 2008). They also consume the gum of *A. senegal*, but it is unclear in what amounts. Swedell et al. (2008) report hamadryas baboons spend 11.6% of their annual feeding time consuming products of *A. senegal*, including the gum, leaves, flowers, and seeds. Interestingly, these central Ethiopian hamadryas baboons also consume latex from two different plant species, the African heartvine (*Pentarrhinum insipidum*) and the Rapunzel plant (*Sarcostemma viminale*).

Baboons, like patas monkeys, often feed from the ground while standing bipedally (Nash 1986). Baboons have no gum feeding specializations of the nails, dentition, or digestive system (Bruorton et al. 1991; Nash 1986). Bruorton et al. (1991) report that, like vervet monkeys, baboons have lower concentrations of volatile fatty acids in the stomach than do folivorous monkeys. But despite their lack of adaptations specific to gummivory, addition of gum to the diet may still be an effective enrichment technique.

Enrichment for Primate Gummivores

Feeding gum in captivity is an important potential way to enrich the lives of primates. Gum arabic, the hardened exudate of *Acacia senegal* and *A. seyal*, is widely available through primate food suppliers and other vendors. It is inexpensive and commercially available because it is used in many food and industrial applications. For example, gum arabic is used in soft drink syrups, in gummy candies, in shoe polish, for viscosity control in inks, as a binder in watercolor paints, and as a lickable adhesive in

postage stamps and cigarette papers. Gum arabic is a complex polysaccharide, and for regulatory purposes is considered a dietary fiber (Phillips et al. 2008). In chemical terms, *Acacia* gums are arabinogalactan proteins, with the component sugars galactose, arabinose, rhamnose, and glucuronic acid. The protein content of *Acacia* gums varies from 0.13% to 10.4% and the dietary fiber content varies from 80% to 90%. These components make gum arabic a nutritious, inexpensive, and readily available food source.

Understanding feeding ecology is an important aspect in formulating enrichment programs. There are many angles to take into consideration, among them nutrition, taste, and temporal and seasonal preferences. One example is the role of tannins in gum preferences. Tannins are astringent, bitter plant polyphenols that cause a dry or puckering feeling in the mouth when consumed (Evert 2006). Wrangham and Waterman (1981) report a negative correlation between food preference and tannin content for vervet monkeys. Nash (1986) states that *G. senegalensis braccatus* rejects gum with added tannin. This is one aspect that must be kept in mind when feeding gum in captivity.

When developing enrichment programs it is also important to consider that foods grown for human consumption, particularly fruits, are much higher in sugar and lower in fiber than their wild counterparts (Crissey et al. 2003). Plesker and Schumacher (2006) show that in a colony of vervet monkeys (*Chlorocebus aethiops*) at the Paul-Ehrlich Institut, Germany, nutrition associated illnesses develop due to preferential eating of enrichment foods. For example, calcium deficiencies, compounded by high dietary vitamin D, contribute to osteoporosis. Other problems include rickets, diverticulosis, and obesity. The authors lament that enriched pellets are not readily available. This shows

that nutritional composition of the diet must be carefully calculated and the health of the animals closely observed.

Some institutions, however, do feed gum and report success. McGrew et al. (1986) write that providing an artificial gum tree to *Callithrix jacchus* increases the occurrence of naturalistic behaviors such as gouging, vertical and quadrupedal clinging, and scent marking. These results are achieved despite only one of the 33 marmosets ever having seen a live tree. The finished, filled gum tree costs less than $10 to make, and a mere five hours to build. At the National Zoological Park in Washington D.C., marmosets and tamarins (*Cebuella pygmaea*, *Callithrix geoffroyi*, *C. melanura*, *Leontopithecus rosalia*, and *L. chrysomelas*) are offered natural branch feeders that simulate gummivory (Kelly 1993). These feeders lead to increased activity by the monkeys, which increases their visibility to zoo visitors, thereby enhancing the experience of visitors to the zoo because they can observe primates engaging in species-typical behaviors. A final example of successful gum feeding in captivity is with red-handed tamarins (*Saguinus midas*) at the Cotswold Wildlife Park in Oxfordshire, UK. (Taylor 2002). The tamarins are provided with two enrichment devices: a hanging feeder basket and sticks suspended from branches and smeared with *Acacia* gum. This leads to a significant increase in feeding and foraging time, reduced stereotypic behaviors such as excessive somersaulting and scent marking, and reduced coprophagy. While coprophagy is a behavior that occurs in the wild and may even be adaptive, in captivity excessive coprophagy may result from stressful situations, boredom, or insufficient dietary roughage (Krief et al. 2004; Prates & Bicca-Marques 2005).

All these studies offer important insights into developing successful enrichment programs. My thesis is one step in the process of collecting information relevant to the enrichment of captive primate gummivores. My aim is to identify enrichment devices and techniques used in zoos worldwide and to assess their effectiveness, expense, and implementation.

CHAPTER II

METHODS

I selected the primate genera in my study based on the amount of gum reported in their wild diets and also their prevalence in zoos. For the sake of clarity and consistency, I chose to use the primate taxonomy outlined by Groves (2001). At the genus level, the study groups (*Euoticus*, *Galago*, *Otolemur*, *Cebuella*, *Callimico*, *Callithrix*, *Leontopithecus*, *Saguinus*, *Erythrocebus*, *Chlorocebus*, and *Papio*) each had at least one species reported to devote 20% or more of the wild diet to exudates. I included every species within the chosen genera to enable surveying as many zoos as possible. Most species within these genera consume gum in the wild, although not all approach 20%. I excluded several gummivorous strepsirhines such as fork-marked lemurs (*Phaner* spp.) and pottos (*Perodicticus potto*) because they were not typically housed in zoos (Huber, unpublished data). It is also important to note that I use the terms "gums" and "exudates" interchangeably. Gum, sap, resin, and latex are structurally, chemically, and nutritionally different (Evert 2006; Lambert 1998), and in some cases, particularly with callitrichids, it is not always clear which types of exudates the animals consume in the wild (Garber 2008, pers. comm.).

I contacted 123 zoos worldwide (See Appendix 1) to request participation in the survey. Seventy-six of these zoos were in the United States and 47 were in other

countries. I selected the zoos to contact using two criteria: [1] the zoo had an English-language website, and [2] at least one species of interest was mentioned on the website. I contacted each zoo via telephone or e-mail, identifying key contact personnel either through the general zoo information address or a staff member listed in the World Directory of Primatologists (http://pin.primate.wisc.edu/idp/wdp). I requested their agreement to participate, but ultimately sent the survey to all zoos for which I obtained an e-mail address other than the general information address, to get as broad a sample as possible. Fifty-eight zoos explicitly agreed to participate and I sent the survey to an additional nine, thus my sample is an opportunistic, rather than a random one. Although it was likely that zoos with extensive environmental enrichment programs were more motivated to participate, the success of my study did not depend on a random or unbiased sample.

I conducted a web-based survey built in *mrInterview* (See Appendix 2 for complete survey), part of the SPSS Dimensions software family. The web-based format was user-friendly and accessible, and therefore likely to increase the response rate. One important benefit of *mrInterview* was that it conditionally displayed questions based on responses to previous questions. For example, once a respondent answered “no” to whether or not the zoo housed marmosets, the survey displayed no further questions related to marmosets. The use of *mrInterview* also significantly reduced individual data entry, thus saving time and reducing errors.

The survey questions were designed to evaluate the types of zoo enrichment used for gummivorous primates worldwide, and to maximize responses. I hoped the survey would be regarded as an opportunity for individual zoos to highlight their enrichment

techniques, rather than to judge or condemn any specific practice or lack thereof. The first six sections of the survey appeared in the following order: patas monkeys, marmosets, tamarins, vervet monkeys, baboons, and galagos. The questions in each of these sections were the same and appeared in a consistent order. The only exceptions were that the section on patas monkeys did not include a question about whether multiple species were housed together (there is only one species of patas monkey), and the galago section included two questions about reversed light cycles (galagos are nocturnal).

Each of these six sets of questions specific to primate groups began with basic questions about number, age, and sex of animals, housing arrangement, and regular diet. These questions were followed by general enrichment questions with room for specification about techniques. The final few questions in each set related specifically to exudate enrichment. These questions were designed to elicit specific information about the form of the gum, how it was presented to the animals, and in what amounts it was provided.

Questions not specific to any one group included whether or not the respondent felt the enrichment was beneficial, whether or not the zoo wanted a final copy of the report, whether or not I could visit the zoo, and whether or not there were any detailed text descriptions, photos, or sketches the zoo was willing to share with me. Because the subject of the survey was not humans or activities impacting humans, it was determined not to need assessment by the Institutional Review Board (IRB).

The amount of time the web-based survey was available to the respondents was limited by cost ($25 per week). The survey was posted on February 14, 2008 and remained active until March 17, 2008. When the survey was first posted, each respondent

received an e-mail containing an html link to the survey and instructions for completion. Reminder e-mails containing the same information as the original e-mails were sent at one-week intervals to respondents who had not yet completed the survey.

Once the web-based survey was offline, I sent an MS Word document version of the survey to each zoo that did not complete the web-based version. The document version contained the same questions in the same order. I requested that each zoo complete the survey document in an effort to increase my sample size. I also sent the document version, as an e-mail attachment, to six zoos that had technical difficulties with the web-based survey. Technical difficulties included lack of Internet access, accidental completion of an unfinished survey, and inability to access the survey website. I offered to pay for return postage; however, all but one of these zoos returned the survey via e-mail. The one zoo that mailed the survey did not take me up on my offer to provide postage.

I also contacted each zoo that indicated a willingness to share more information. I requested that the zoo e-mail or mail by post any available information in the form of text descriptions, photographs, or sketches. Once again, I offered to pay for postage, but no zoos accepted my offer.

Through analysis of the data I found that four zoos began the survey, but did not complete it. I e-mailed each of these zoos to request completion. I copied and pasted the information already provided by the zoo into a document version of the survey and included the document as an attachment to be completed and returned by e-mail or post. I also identified four zoos that only answered the first survey question. I eliminated these zoos entirely from the dataset.

Four zoos filled out two surveys each. Two respondents from a single zoo were sometimes necessary when the zoo housed multiple survey species cared for by different staff members. For double-responding zoos I consolidated all the information provided into a single response line. I did not make any other changes to the data in the process.

For patas monkeys, I found that only three zoos responded, none of which reported feeding gum. Because patas monkeys in the wild consume a significant amount of gum year round (unlike other cercopithecines), and because my sample size of zoos with patas monkeys was so small, I wanted to know if my sample accurately reflected the population. I identified 15 zoos that housed patas monkeys (according to their websites), but did not respond to my survey. I e-mailed each of these zoos, simply asking if they fed gum to their patas monkeys. Four zoos responded, none of which reported feeding gum. Thus it seems my sample accurately reflects the population, although the sample size is still quite small. Additionally, one of these four responding zoos agreed to complete the entire survey, and did so in the document form described above.

In August 2008 I visited two zoos to see the environmental enrichment programs in person. I chose the Phoenix Zoo and Houston Zoo because each reported feeding gum to callitrichids and because of the financial feasibility of visiting the locations. At the Phoenix Zoo I met with keeper Terasa Fleshman and watched the feeding and training of golden lion tamarins (*Leontopithecus rosalia*), cotton-top tamarins (*Saguinus oedipus*), and white-headed marmosets (*Callithrix geoffroyi*). I also watched as Terasa prepared gum feeders and hung them in the exhibits, and I casually observed the responses of the animals. At the Houston Zoo I met with keeper Lynn Killam, who gave me a tour of the primate section of the zoo and an overview of the diets and environmental enrichment

programs for patas monkeys and several callitrichids (*Cebuella pygmaea*, *L. rosalia*, *S. bicolor*, and *S. oedipus*). These two zoo visits allowed me to see in person two of the methods used for feeding gum in captivity: log feeders and spreading gum on exhibit material.

CHAPTER III

RESULTS

Forty-six zoos completed the survey (69% of zoos to which surveys were actually sent; 37% of zoos initially contacted; See Appendix 1). Twenty-six of the responding zoos are in the United States, nine in England, two in Australia, one in Germany, one in Greece, one in Hong Kong, one in New Zealand, one in Northern Ireland, one in the Republic of Ireland, one in Scotland, one in Singapore, and one in Sweden. Altogether, these zoos house a minimum of 794 individual gum-eating primates (a few zoos did not report the exact number of animals). When taking into account all six primate groups (galagos, marmosets, tamarins, patas monkeys, vervet monkeys, and baboons), 27 of the 46 zoos feed gum to at least one primate group (59%). See Table 1 for a summary of the number of zoos that house and/or feed gum to each primate group. The complete dataset is available online: http://spreadsheets.google.com/pub?key=pUMfBZMyuNkvXMFakIytlWw.

Galagos

Six zoos report housing galagos (13% of zoos surveyed), with 13 total individual galagos. Two zoos house lesser galagos (*Galago senegalensis*), two zoos house mohol

galagos (*Galago moholi*), one zoo houses greater galagos (*Otolemur crassicaudatus* or *O. garnettii*), and one zoo houses unspecified galagos.

Gum-Based Enrichment See Table 2. Three of the six zoos reported feeding gum to galagos (50%). Of these, one zoo feeds powdered gum (33%) and two zoos (67%) feed crystallized gum arabic dissolved in water. None of the zoos mix the gum with anything other than water.

Timing & Gum Feeding Devices See Table 2. Of zoos that house galagos, two feed gum in the afternoon (1200–1659 hours) and one feeds gum in the morning (0500–1159 hours). One zoo puts the gum in a log feeder, one zoo puts the gum in an undescribed foraging device, and one zoo puts the gum in a dish.

Other Enrichment Five of the six zoos that house galagos use extractive foraging devices for enrichment (83%). Four use puzzle feeders (67%), four use dispersed food (67%), and two use hidden food (33%). Other enrichment types are very similar to types used for callitrichids. Additionally, four zoos use a reversed light cycle in galago exhibits (67%). The lights are controlled by a timer and turn on from 1000–1900 hours, 0900–1830 hours, 0900–2100 hours, or 1000–2100 hours.

Aggression All six zoos reported never seeing aggression over enrichment with galagos. Preventative methods include using multiple feeding stations and providing more than enough for all the galagos.

Diet Most zoos feed a diet of fruits, vegetables, insects, and some type of prepared primate diet, like canned primate diet or monkey chow. Other foods include cat food, cheese, baby food, and raisins. One zoo uses a number of dietary supplements, including Abidec (multivitamin), Cytacon (vitamin B12), and grated cuttlefish (calcium).

Table 1: Number of zoos that house each primate group and number of zoos that feed gum to each primate group. (Percentages for "house" are based on N = 46 and percentages for "feed gum" are based on number for "house.")

	House	Feed gum
Tamarins	38 (83%)	19 (50%)
Marmosets	30 (65%)	25 (83%)
Galagos	6 (13%)	3 (50%)
Baboons	12 (26%)	0
Patas Monkeys[i]	4 (9%)	0
Vervet Monkeys	3 (7%)	0

[i]An additional three zoos that did not respond to the complete survey reported that they do not feed gum to patas monkeys; thus, seven total zoos do not feed gum to patas monkeys.

Table 2: Gum-based enrichment techniques and timing for marmosets, tamarins, and galagos.

	Marmosets	**Tamarins**	**Galagos**
Number of zoos that house[i]	30 (65%)	38 (83%)	6 (13%)
Number of zoos that feed gum[ii]	25 (83%)	19 (50%)	3 (50%)
Form of gum[iii]			
Powdered	22 (88%)	17 (89%)	1 (33%)
Crystallized	5 (20%)	2 (11%)	2 (67%)
Raw (unprocessed)	6 (24%)	1 (5%)	0 (0%)
Method of gum feeding[iv]			
Dish	9 (36%)	8 (42%)	1 (33%)
Log feeder	7 (28%)	7 (37%)	1 (33%)
Foraging Device	7 (28%)	4 (21%)	1 (33%)
Spread on exhibit material	6 (24%)	4 (21%)	1 (33%)
Fresh branches	1 (4%)	0 (0%)	0 (0%)
Injected into gouged holes	1 (4%)	NA	0 (0%)
Time of gum feeding[v]			
Morning (0500–1159 hours)	10 (40%)	5 (26%)	1 (33%)
Afternoon (1200–1659 hours)	18 (72%)	17 (89%)	2 (67%)
Evening (1700–2059 hours)	2 (8%)	1 (5%)	0 (0%)
Night (2100–0459 hours)	0 (0%)	0 (0%)	0 (0%)

[i] Percentage based on N = 46
[ii] Percentage based on "number of zoos that house."
[iii] Percentage based on "number of zoos that feed gum."
[iv] Percentage based on "number of zoos that feed gum."
[v] Percentage based on "number of zoos that feed gum."

Marmosets

Thirty zoos reported housing marmosets (65% of zoos surveyed), with a minimum of 220 total individual marmosets (a few zoos did not report the exact number of marmosets). Pygmy marmosets (*Cebuella pygmaea*) are the most commonly housed species, with 22 zoos in total housing a minimum of 113 animals. The next most common species is *Callithrix geoffroyi* (ten zoos with a minimum of 43 marmosets). Other marmosets housed in responding zoos include *Callithrix argentata* (five zoos with a minimum of 17 marmosets), *Callimico goeldi* (four zoos with 13 marmosets), *Callithrix jacchus* (three zoos with 13 marmosets), *Callithrix penicillata* (three zoos with 12 marmosets), and *Callithrix kuhlii* (two zoos with nine marmosets). See Appendix 3 for a breakdown of gum feeding techniques and timing for each species of marmoset.

Gum-Based Enrichment See Table 2. Twenty-five zoos reported feeding gum to marmosets (83% of zoos that house marmosets). Of these, 22 zoos feed powdered gum (88%), five feed crystallized gum arabic (20%), and six feed raw gum (either collected outside the exhibit or harvested by the marmosets from a tree within the exhibit; 24%). The gum is usually not mixed with other ingredients aside from water for reconstitution; however one zoo adds sugar and another adds fruit juice.

Timing & Gum Feeding Devices See Table 2. Of zoos that feed gum to marmosets, ten feed gum in the morning (0500–1159 hours; 40%), 18 feed gum in the afternoon (1200–1659 hours; 72%), and two feed gum in the evening (1700–2059 hours; 8%). No zoos feed gum at night (2100–0459 hours). Although not all zoos reported the method for providing gum, the breakdown is as follows: nine zoos put gum in a dish (36% of gum feeding zoos), seven zoos put gum in an undescribed extractive foraging device (28%),

seven zoos put the gum in holes drilled in wood (28%), six zoos spread gum on branches (24%), one zoo spreads gum on toys (4%), one zoo puts gum into holes gouged by marmosets in a tree within the exhibit (4%), and one zoo provides fresh branches with exuding gum (4%). Additionally, free-ranging marmosets at the Durrell Wildlife Conservation Trust reportedly consume exudates from cherry trees within the zoo.

Other Enrichment Zoos also reported a wide range of enrichment techniques not involving gum feeding. Of zoos that house marmosets, 22 hide food in the exhibit (73%), 22 use extractive foraging devices (73%), 22 disperse food around the exhibit (73%), and 20 use puzzle feeders (67%). Popular enrichment methods include hanging baskets, Kongs™, kabobs, coconut feeders, and boxes or tubs filled with foraging substrate and treats.

Aggression Aggression over food and enrichment is reportedly rare with marmosets. Nineteen zoos report rarely or never witnessing aggression provoked by enrichment (63% of zoos that house marmosets). Techniques recommended by respondents for dealing with aggression include removing the provoking item, having one or more enrichment items per animal, separating the aggressor, spacing out enrichment, and providing a wide variety of enrichment items.

Diet The regular diets for the marmosets, although quite variable, are generally of similar composition. Most zoos feed some kind of prepared primate diet, such as canned marmoset diet, monkey chow, or monkey pellets. In addition, all zoos provide a combination of fruits, vegetables, and insects (presumably live). Types of fruits and vegetables are highly variable, but insects mostly consist of mealworms (18 zoos- 60% of zoos that house marmosets), crickets (nine zoos- 30%), locusts (five zoos- 17%), and

waxworms (four zoos- 13%), although one zoo (3%) reports feeding wax moths, one feeds grasshoppers, and another feeds baby hissing cockroaches. Other foods include eggs (boiled or unspecified, ten zoos- 33%), callitrichid or marmoset jelly/gel (eight zoos- 27%), cooked chicken (five zoos-17%), baby food (four zoos- 13%), bread (four zoos- 13%), cheese (four zoos- 13%), nuts (three zoos- 10%), raisins (three zoos- 10%), milupa baby formula (two zoos- 7%), seeds (two zoos- 7%), cooked rice (two zoos- 7%), cat food (one zoo- 3%), yogurt (one zoo- 3%), and dates (one zoo- 3%). Several zoos also mentioned feeding dietary supplements, such as vitamin D (e.g. Vigantol oil), multivitamin liquids or powders (e.g. Abidec, SA37, and Complan), calcium (e.g. grated cuttlefish, Nutrobal, and Calcivit), protein (e.g. Casilan), and vitamin B12 (e.g. Cytacon).

Tamarins

Thirty-eight zoos reported housing tamarins (83% of zoos surveyed), with a minimum of 412 total individual tamarins (a few zoos did not report the exact number of tamarins). *Saguinus oedipus* is the most commonly housed species, with 25 zoos housing a minimum of 115 tamarins. The next most common species is *Leontopithecus rosalia*, with 23 zoos housing a minimum of 88 tamarins. Other tamarins housed in responding zoos include *L. chrysomelas* (14 zoos with 42 tamarins), *S. imperator* (14 zoos with a minimum of 52 tamarins), *S. bicolor* (11 zoos with a minimum of 47 tamarins), *S. midas* (four zoos with 12 tamarins), *L. chrysopygus* (three zoos with a minimum of 15 tamarins), *S. geoffroyi* (three zoos with 21 tamarins), *S. mystax* (two zoos with 10 tamarins), *S. labiatus* (two zoos with eight tamarins), and *S. fuscicollis* (two zoos with a

minimum of two tamarins). See Appendix 3 for a breakdown of gum feeding techniques and timing for each species of tamarin.

Gum-Based Enrichment See Table 2. Nineteen zoos reported feeding gum to tamarins (50% of zoos that house tamarins). Of these, seventeen zoos feed powdered gum (89%), two zoos feed crystallized gum arabic (11%), and one zoo feeds raw gum (5%). The gum is usually not mixed with other ingredients aside from water for reconstitution; however one zoo adds sugar, one zoo adds banana and Protexin (a probiotic), and one zoo adds blueberry juice. Interestingly, both the zoo that adds banana and the zoo that adds blueberry juice use these added ingredients for *S. bicolor* (pied tamarins) only, and not for the multiple other tamarin species housed at each zoo. One of these zoos reports that *S. bicolor* seem to require more enrichment than the other two species housed at the zoo (*L. rosalia* and *S. oedipus*). The other zoo reports feeding gum to *S. bicolor* twice as often as to the other species housed at the zoo (*S. imperator*); gum is fed to *S. bicolor* every day, but only every other day to *S. imperator*.

Timing & Gum Feeding Devices See Table 2. Of zoos that feed gum to tamarins, five feed gum in the morning (0500–1159 hours; 26%), 17 feed gum in the afternoon (1200–1659 hours; 89%), and one feeds gum in the evening (1700–2059 hours; 5%). No zoos feed gum at night (2100–0459 hours). The most popular serving method for gum is simply placing it in a dish (eight zoos; 42% of gum feeding zoos); this is also the most popular method for feeding gum to marmosets. Seven zoos put the gum into holes drilled into a piece of wood (37%), four zoos put the gum in an extractive foraging device (21%), and four zoos spread the gum on branches (21%).

Other Enrichment Other types of enrichment are quite similar to enrichment for marmosets; out of 25 zoos that house both tamarins and marmosets, 15 zoos report using the same enrichment techniques for each. At least seven of these zoos house marmosets and tamarins in the same exhibit, although it is not always clear from the exhibit descriptions if this is the case. Out of 38 zoos that house tamarins, 27 report hiding food (71%), 26 report using puzzle feeders (68%), 26 report dispersing food (68%), and 24 report using extractive foraging devices (63%).

Aggression Aggression over enrichment is reportedly uncommon for tamarins. Twenty-two zoos report rarely or never witnessing aggression (58% of zoos that house tamarins). When aggression does occur, recommended techniques for remedying the situation include having at least one enrichment item per animal, spreading out the enrichment, separating the aggressor, or removing the provoking item.

Diet Diets for tamarins are reportedly very similar to diets for marmosets. Most zoos feed a combination of prepared primate diet (such as canned marmoset diet or monkey chow), fruits, vegetables, and insects. Fruit and vegetable types are highly variable, but insect types are more limited. Of zoos that house tamarins, 23 feed mealworms (61%), 15 feed crickets (39%), eight feed waxworms (21%), six feed locusts (16%), two feed grasshoppers (5%), two feed superworms (5%), and two feed hornworms (5%). Insects fed by only one zoo each (3%) include maggots, silkworms, walking sticks, and wax moths. Other food fed to tamarins include eggs (raw or cooked; 17 zoos- 45%), cooked meat (six zoos- 16%), bread (six zoos- 16%), callitrichid jelly (five zoos- 13%), cheese (five zoos- 13%), nuts (four zoos- 11%), seeds (three zoos- 8%), honey (three zoos- 8%), raisins (three zoos- 8%), yogurt (two zoos- 5%), baby food (two zoos- 5%), milupa baby

formula (two zoos- 5%), cereal (two zoos- 5%), and cooked rice (two zoos- 5%). Foods mentioned by one zoo each (3%) include popcorn, juice, applesauce, oats, bran, dates, hibiscus, olives, ginger, celtis (hackberry), macaroons, peanut butter, jelly, and cat food. Several zoos also feed dietary supplements, sometimes mixed with baby food or sprinkled on other items in the diet. Supplements include vitamin D (e.g. Vigantol oil), multivitamin liquid or powder (e.g. Abidec, SA37, and Complan), calcium (e.g. grated cuttlefish, Nutrobal, Calcivit, and CaC03 powder), protein (e.g. Casilan), and vitamin B12 (e.g. Cytacon).

Patas Monkeys

Four zoos reported housing *Erythrocebus patas* (9% of zoos surveyed), with 15 total individual patas monkeys.

Gum-Based Enrichment None of the zoos reported feeding gum to the patas monkeys.

Other Enrichment Of the four zoos that house patas monkeys, three hide food (75%), three disperse food (75%), two use puzzle feeders (50%), and one uses extractive foraging devices (25%). Other enrichment types include feeding novel or cooked food, hiding food in boxes or bottles (sometimes with substrate), and smearing food on phone books or paper towel tubes. One zoo reported lack of success with puzzle feeders, attributing disinterest to lack of motivation.

Aggression Two zoos reported no aggression over enrichment and one zoo reported witnessing minor spats. The only suggestion for handling aggression is spreading the enrichment around the exhibit.

Diet All four zoos reported feeding a regular diet of fruits, vegetables, and prepared primate diet, such as leafeater biscuits, browse biscuits, or growth and reproduction biscuits. Three of these zoos (75%) also feed insects, including mealworms, waxworms, crickets, and hornworms. Three zoos each (75%) feed nuts, seeds, and eggs, and two zoos each (50%) feed popcorn, cereal, pasta, frozen fruits and vegetables, and dried fruit. Other foods mentioned by only one zoo each (25%) include oats, bran, honey, peanut butter, jam, baby food, juice, applesauce, yogurt, legumes, browse, rice cakes, cooked rice, crackers, and peanut butter and jelly sandwiches.

Vervet Monkeys

Three zoos reported housing *Chlorocebus aethiops* (7% of zoos surveyed), with 26 total individual vervet monkeys.

Gum-Based Enrichment No zoos reported feeding gum to vervet monkeys.

Other Enrichment All three zoos use hidden and dispersed food and two (67%) use extractive foraging devices. Other enrichment types include plastic drinking bottles, hanging baskets filled with food and hay or grass, fruit kabobs, frozen fruit, branches spread with honey and dried fruit, toys, and browse.

Aggression Two zoos (67%) reported never witnessing aggression over enrichment. Advice for dealing with aggression includes providing more devices than monkeys and separating the aggressor.

Diet Captive vervet monkeys eat a combination of fruits and vegetables along with prepared primate diet (e.g. leafeater pellets). Other foods include eggs, pasta, dried fruit, cooked chicken, mealworms, and seeds.

Baboons

Twelve zoos reported housing baboons (26% of zoos surveyed), with a minimum of 108 total individual baboons. Two zoos did not report the exact number of animals. Fifty-four of these baboons (50%) are housed at one zoo. Seven zoos house hamadryas baboons (*Papio hamadryas*), two house mandrills (*Mandrillus sphinx*), and one houses guinea baboons (*Papio papio*).

Gum-Based Enrichment Only one zoo reported that the baboons eat gum. Hamadryas baboons (*P. hamadryas*) eat gum from an *Acacia* spp. naturally occurring in the exhibit at the Perth Zoo in Australia.

Other Enrichment Of zoos that house baboons, eleven use puzzle feeders (92%), ten use dispersed food (83%), ten use hidden food (83%), and eight use extractive foraging devices (67%). Other types of enrichment include boxes, baskets, balls, logs, foraging substrate, and frozen treats.

Aggression Of zoos that house baboons, three reported never seeing aggression (25%) and three reported only occasional aggression (25%). Suggestions for handling aggression include spreading out the food and enrichment devices, separating baboons during preferred food feeding, discontinuing use of provoking items, feeding dominant baboons first, varying the location of enrichment items, and engaging the baboons in cooperative feeding training. One zoo (8%) reported always separating baboons during feeding time, and three others (25%) reported separation during feeding some of the time.

Diet Zoo baboons eat a combination of fruits, vegetables, and prepared primate diet, such as monkey chow or leafeater biscuits. Of zoos that house baboons, three (25%) feed

seeds and two zoos each (17%) feed nuts, cereal, eggs, and popcorn. Foods fed by one zoo each (8%) include waxworms, mealworms, crickets, juice, applesauce, oats, bran, honey, peanut butter, jelly, yogurt, baby food, saltine crackers, bread, and dried fruit.

September 2008 visit to the Phoenix Zoo:

During my visit to the Phoenix Zoo, keeper Terasa Fleshman placed horizontal log feeders filled with gum arabic in three exhibits. I informally observed the reactions of the monkeys. One exhibit contained two cotton-top tamarins (*Saguinus oedipus*), one exhibit contained two white-headed marmosets (*Callithrix geoffroyi*), and the other exhibit contained two golden lion tamarins (*Leontopithecus rosalia*). The cotton-top tamarins were apparently the least interested in the gum. Both cotton-top tamarins approached the feeder and tasted the gum, but did not return for more (Figure 1). In keeper Fleshman's estimation, this could easily have been due to the tamarins' nervousness about my presence. The two white-headed marmosets seemed more interested in the gum feeder, and appeared to eat quite a bit, both staying near the feeder for several minutes (Figure 2). The golden lion tamarins were by far the most interested in the gum, and consumed it all quickly (Figure 3). One golden lion tamarin even ate additional gum out of the syringe keeper Fleshman used to inject the gum into the feeder (Figure 4). (The tamarins are familiar with syringes, as they are filled with condensed milk for use during training.)

Figure 1: Cotton-top tamarin (*Saguinus oedipus*) using gum feeder

Figure 2: White-headed marmosets (*Callithrix geoffroyi*) using gum feeder

Figure 3: Golden lion tamarin (*Leontopithecus rosalia*) using gum feeder.

Figure 4: Golden lion tamarin (*Leontopithecus rosalia*) eating gum from a syringe.

CHAPTER IV

DISCUSSION

The State of Gum-Based Environmental Enrichment in Zoos

The majority of zoos surveyed feed gum to at least one species of primate gummivore (59%). However, not a single zoo reported feeding gum to cercopithecines. Fifty percent of zoos reported feeding gum to galagos and tamarins and 83% reported feeding gum to marmosets, usually in the form of gum arabic. Importantly, even zoos that do feed gum do not do it in particularly naturalistic ways. Encouraging species-typical behaviors is the primary goal of environmental enrichment programs (Kreger et al. 1998; Lindburg 1998; Mellen & MacPhee 2001; Poole 1998; Seidensticker & Forthman 1998; Shepherdson 1998; Young 2003). Therefore, the main purpose of feeding gum to captive primates is to provide opportunities for displaying species-typical behaviors.

For marmosets and tamarins, the most common method for providing gum is to put it in a dish (marmosets: 9 of 25 gum-feeding zoos; tamarins: 8 of 19), although only one of three zoos feeds gum in a dish to galagos. Feeding gum in a dish does not provide the opportunity for naturalistic foraging behaviors, as in the wild many species of marmosets, tamarins, and galagos feed on gum while vertically clinging to large tree trunks (Garber 1987; Garber 1992; Garber & Leigh 2001; Nash 2001). Other methods of

gum-feeding in captivity, such as log feeders (galagos: 1 of 3 gum-feeding zoos; marmosets: 7 of 25; tamarins 7 of 19) and other foraging devices (galagos: 1 of 3 gum-feeding zoos; marmosets: 7 of 25; tamarins 7 of 19), are less popular. These methods are significantly more naturalistic than dishes. Constructing a log feeder is inexpensive and can be accomplished with only a small investment of time. (See Appendix 4 for instructions for constructing a simple log feeder.) Spreading gum on exhibit material, such as cage bars or perches (galagos: 1 of 3 gum-feeding zoos; marmosets: 6 of 25; tamarins: 4 of 19), can be an effective technique if the circumstances allow animals to exhibit clinging behavior. The most naturalistic ways of feeding gum, providing fresh branches (marmosets: 1 gum-feeding zoo) or injecting gum into holes within wood in the exhibit (marmosets: 1 gum-feeding zoo), are hardly utilized at all.

One zoo asserts that pied tamarins (*Saguinus bicolor*) seem to need more enrichment than other tamarins; a second zoo reports feeding gum to pied tamarins twice as often as to other tamarins. It is difficult to know if pied tamarins do, in fact, require more enrichment than other tamarins. Nevertheless, feeding gum in ways that encourage species-typical behaviors is an ideal avenue for increasing the breadth of enrichment for any gum-eating species, pied tamarins included.

Only two zoos report observing primates eating gum exuded from live trees. At the Durrell Wildlife Conservation Trust in England, marmosets apparently forage gum from cherry trees. Surprisingly, the other of these two cases is from hamadryas baboons (*Papio hamadryas*) at the Perth Zoo in Australia, who have been observed procuring gum from an *Acacia* spp. in their exhibit. This in itself is evidence, admittedly anecdotal (Bates & Byrne 2007), that captive cercopithecines will actively forage for gum when

given the opportunity. This is not surprising, given that baboons, vervet monkeys, and patas monkeys consume gum in the wild (Altmann 1998; Isbell 1998; Isbell & Young 2007; Nakagawa 2000; Nash 1986; Paterson 2006; Swedell 2002; Swedell et al. 2008; Wrangham & Waterman 1981).

Nevertheless, no zoos report intentionally feeding gum to cercopithecines. This is particularly shocking in the case of patas monkeys, which in the wild devote 20% of their feeding time to the gums of *Acacia* spp. (Isbell 1998; Isbell & Young 2007; Nash 1986). This level of importance in the wild diet of patas monkeys is matched only by their consumption of arthropods (e.g., ants). Three of four zoos that house patas monkeys report feeding insects, but two of the three do not feed insects every day. Interestingly, one zoo reports a lack of success using puzzle feeders with patas monkeys, attributing the monkeys' disinterest to lack of motivation. Perhaps the problem is with the food within the feeders? This particular zoo does not feed gum or insects, but instead uses birdseed as enrichment food. Through my correspondence with patas monkey keepers it is clear that most are unaware that patas monkeys consume gum in the wild. These findings are clear evidence that zookeepers, at least in some cases, are poorly informed about the wild diets of the primates for which they care. This problem must be addressed.

Improving Communication between Researchers and Caretakers

Primate field studies do not serve merely to fulfill the intellectual curiosity of researchers. Understanding the diets of wild primates has practical applications too. One important application is utilizing knowledge of wild behavior to improve the welfare of captive primates. Zoo exhibit designs, feeding schedules, and enrichment programs should ideally be based on observations of how animals behave in their natural habitats

(Mellen & MacPhee 2001; Shepherdson 1998). This not only benefits the animals, but also visitors to zoos, who have the opportunity to observe animals engaging in species-typical behaviors. One of the primary goals of public zoos is education (Kreger et al. 1998; Seidensticker & Forthman 1998; Shepherdson 1998). The level of education provided by zoos is greatly improved through exhibits that resemble the natural habitats of the animal occupants. The more species-typical behaviors an animal displays, the more educational and enjoyable the exhibit, and the more likely zoo visitors will sympathize with the conservation effort (Markowitz & Aday 1998; Shepherdson 1998).

For these reasons, providing environmental enrichment that encourages species-typical behaviors is definitely in the best interest of zoos. But ensuring that knowledge gained from wild field studies informs captive care is not only the job of zookeepers and other zoo staff. It is equally the responsibility of those who study wild animals. Playing an active role in improving the welfare of captive primates is a fulfilling and critical pursuit. There are a variety of ways that primatologists and other researchers can strengthen communication between those in academia and those in captive primate care.

1. Get in touch with a local zoo. In conducting this survey I became involved in correspondence with zoos all over the world. Zoo employees were overwhelmingly receptive to discussing their enrichment programs, evidenced not only by the 67% response rate to the survey, but also by the hundreds of additional photographs, detailed descriptions of enrichment devices, dietary schedules, and taxon reports sent to me by zoo employees. Based on these communications I think it is fair to assert that animal keepers care deeply for their charges and seek to provide the best possible environment. Opening the doors of

communication between animal caretakers and animal researchers should be an easy task, as long as we turn the knobs!

2. Send relevant reading materials to animal caretakers. Many zoos lack the funding and/or time to subscribe to and read a wide variety of peer-reviewed journals. In my experience, zookeepers greatly appreciate interesting and relevant reading material. Indeed, keepers at the Houston Zoo expressed immediate desire to incorporate gum arabic into the diet of their patas monkeys upon reading a few pertinent articles.
3. Help prepare proposals. In some zoos, such as the Phoenix Zoo, keepers are required to submit proposals before introducing new foods or other enrichment items. In many cases, particularly in zoos that do not receive government support, keepers have little to no spare time for researching and writing proposals. Providing assistance with this task has the potential to be of huge benefit to zookeepers and the animals in their care.
4. Actively engage in enrichment research, design, and implementation. Although this is obviously a time consuming task, it is a necessary one. For primate gummivores, particularly patas monkeys, there is a marked lack of similarity between captive and wild environments. This means that there has not been enough effort devoted to environmental enrichment design. Academics and caretakers must team up to improve this situation.

I want to emphasize that I do not intend to place blame on any party. Rather, I view this report as research into which areas of environmental enrichment deserve further attention. Environmental enrichment is a developing field and there are certainly holes to

be filled. Animal caretakers did not begin incorporating knowledge of wild behaviors into formulating captive environments until the 1960s (Mellen & MacPhee 2001) and the first legislative recognition of the importance of environmental enrichment was not until 1985, with the Animal Welfare Act (Mench 1998). Environmental enrichment has come a long way since then, and I hope my research contributes to its future progress.

Incorporating Gum into the Captive Primate Diet

Procuring and Preparing Gum

Food-grade gum arabic can be purchased from a wide variety of sources, and is easily found with a quick Internet search. The Phoenix Zoo purchases gum arabic from Primatestore.com. (For ease of locating gum arabic on this website, go directly to: http://www.webstorespro.com/ps/monkey_supplements.asp.) This site sells 1 lb. of gum arabic for $20. It is difficult to estimate how many servings are in 1 lb. and it will, of course, differ for each primate. But for the sake of making the amounts at hand clearer, if a single callitrichid or galago serving consists of 1/4 ounce (2 teaspoons of powder or 1 tablespoon of reconstituted gum), then 1 lb. of gum arabic contains 64 servings at $0.31 each. (These measurements are based on a sample of gum arabic powder generously provided by Jumbo Trading Company.) At the time of writing, twenty dollars a pound appears to be an average price based on a quick and informal Google-shopping search, which revealed hundreds of companies selling 1 lb. of gum arabic for $13 to $30. (Many of these online stores are nutritional supplement suppliers, and tout the alleged health benefits of consuming gum Arabic, such as its use as a prebiotic and as a source of dietary fiber.)

Gum arabic is typically purchased in powder form and must be reconstituted with water. Primatestore.com recommends mixing one part gum arabic powder with two parts water. The reconstituted gum is ready to use within a few hours. Other ingredients, such as fruit juice or mashed fruit, can be added to increase palatability, although additives are unnecessary. Only three zoos report using additives, including sugar, mashed banana, and blueberry juice. The consistency is that of a gel or syrup. The gum can be spread on branches, perches, or other exhibit materials, or can be injected with a syringe into a log feeder or into holes in wood within the exhibit. In the case of marmosets, gum may be injected into holes gouged by the marmosets themselves. According to McGrew et al. (1986), even captive marmosets that have never seen a live tree will gouge holes in their exhibit and consume gum arabic from a log feeder device. This is because gouging is a species-specific trait, making it all the more important to support and encourage this behavior through environmental enrichment.

Of course, fresh branches with exuding gum can also be provided. This is especially feasible in climates where *Acacia* spp. thrive (e.g., the American southwest); branches can be trimmed from trees within or around the zoo. While visiting the Phoenix Zoo, Dr. Leanne Nash and I found *Acacia* trees growing all over the zoo property. After we pointed this out to keeper Fleshman, she requested that the landscaping staff begin providing her with branch trimmings. Spraying dry branches with water may make them more attractive to the animals (Nash 2008, pers. comm.). Obviously, the most naturalistic way to provide gum in captivity is to have a gum-exuding tree in the exhibit. Since having a gum tree in the exhibit is not feasible in many cases (due to problems with

freezes during winter), providing fresh branches and/or injecting gum into holes within the exhibit are the next best alternatives.

Although exudates from *Acacia* spp. are eaten in the wild by cercopithecines and galagos, wild callitrichids consume exudates from other sources, as *Acacia* are not native to or typical in the New World. Currently, little is known about the differences in nutritional composition between exudates from *Acacia* spp. and other exudate food sources for primates (Garber 2008, pers. comm.). However, gum arabic has been successfully used in captivity by a number of published studies (Kelly 1993; McGrew et al. 1986; Taylor 2002) as well as in many of the zoos surveyed for this study. It is important to note that the purpose of environmental enrichment is not nutritional; primates in captivity should receive appropriate nutrition from formulated primate diets, such as monkey chow and canned marmoset diet. Instead, environmental enrichment is used to stimulate species-typical behaviors seen in the wild, like tree-gouging (Kreger et al. 1998; Lindburg 1998; May & Lyles 1987; Mellen & MacPhee 2001; Poole 1998; Seidensticker & Forthman 1998; Shepherdson 1998; Young 2003). Thus, gum arabic can be used successfully with captive callitrichids despite the fact that callitrichids do not consume *Acacia* exudates in the wild. The same argument can be applied to the use of callitrichid or marmoset jelly/gel. Almost one-third of zoos report feeding callitrichid or marmoset jelly/gel, and in a few cases even confuse these products with gum. While the consistency of these products can be similar to that of gum, they are not nutritionally equivalent. Callitrichid or marmoset jelly/gel is typically high in protein and low in fiber, exactly the opposite of gum arabic. Nevertheless, it is certainly possible to use them in similar ways as gum, thus simulating wild feeding behavior. Despite the fact that

callitrichid or marmoset jelly/gel can be used as a substitute for actual tree exudates, it is important to note that keepers lack knowledge on the difference between a naturally occurring tree exudate and a manmade commercial product. This is equivalent to mistaking a primate biscuit for a nut. They may look and feel alike, but they are not the same thing. It is feasible that some of the zoos that report feeding gum to primates are actually feeding jelly/gel. I was able to catch this in a few cases through post-survey conversation with keepers, but it seems likely that other cases of this confusion exist.

Timing

The majority of zoos feed gum in the afternoon (from 12:00pm - 4:59pm). This is in line with current knowledge of the process of digesting gum in tamarins. Because gums are made of complex polysaccharides, digestion is assisted by fermentation in the hindgut (Caton et al. 2000; Nash 1986; Nash & Whitten 1989). While marmosets and galagos likely have adaptations for digesting gum (Caton et al. 1996; Power & Oftedal 1996), tamarins do not. However, as discussed above, Heymann and Smith (1999) report a temporal preference by wild tamarins for feeding on gum in the late afternoon. They hypothesize that feeding in the afternoon allows for an increased amount of time for digestion. For this reason, it may be beneficial to feed gum to tamarins in the late afternoon.

Other Enrichment Suggestions

As the wild gummivore diet often places a heavy emphasis on insectivory, insect houses and plantings that encourage insects to visit are effective forms of environmental enrichment for primates that feed on exudates in the wild. See Figure 5 for the creative device used by the Durrell Wildlife Conservation Trust. This device serves as an insect

house, and encourages a self-sustaining insect population. Primates may then forage for the insects. Having real plants in the exhibit is also effective, and even edible plants may be used. For example, the Hogle Zoo in Utah reports planting nasturtiums in callitrichid exhibits. They recommend building a planter with a fine mesh covering so that the animals cannot pull the plants up by the roots. Zoo Montana plants squashes, such as zucchini, which have edible flowers as well as fruits (Figure 6).

Figure 5: Pied tamarin (*Saguinus bicolor*) using insect feeder.

Photo courtesy of Durrell Wildlife Conservation Trust.

Figure 6: Pygmy marmoset (*Cebuella pygmaea*) next to a potted squash plant.

Photo courtesy of Zoo Montana.

Speculation on Potential Gum Feeding Methods for Cercopithecines

No zoos report feeding gum to cercopithecines and I have found no literature on gum feeding techniques for cercopithecines; thus, I can only speculate on what may work. In Africa and the Middle East, gum accumulates in large, hardened globs on the

trunks of *Acacia* trees. Patas monkeys anchor the jaw against gum substrate using the lower incisors and scrape gum using the upper incisors (Figure 7) (Nash 1986). To simulate this in captivity, gum arabic could be dried in a large clump on a piece of wood or other material and placed within the exhibit. This is more difficult than it sounds, as pouring reconstituted gum arabic over a branch and letting it dry does not result in a large clump, just a thin coating. One possible method is to glue chunks of crystallized gum arabic onto the desired material using reconstituted gum arabic as an adhesive. This gluing procedure works quite well, but it is unknown whether or not the glue would hold up to foraging activity. Alternatively, powdered gum may be reconstituted with substantially less water than is usually used so that it can be clumped and dried on the desired material without the problem of runniness. Additional experimentation is certainly warranted.

Figure 7: Patas monkey (*Erythrocebus patas*) feeding from an *Acacia* spp.
Photo courtesy of Dr. Lynne Isbell.

CHAPTER V

CONCLUSION

The majority of zoos provide exudates to gummivorous primates, but zoos that provide exudates typically do not provide enrichment devices that emulate naturalistic retrieval of exudates. This is particularly pronounced in the case of patas monkeys, obligate gummivores that do not receive any gum in captivity. Anthropologists are in a position to work with zoos to improve the quality of life for these primates. Environmental enrichment that promotes naturalistic behavior enhances the psychological wellbeing of animals, thus exudate feeding is likely to be important to the welfare of captive gummivores. Captive primate nutrition is appropriately provided by formulated diets (e.g., monkey chow), so the value of feeding exudates is in encouraging behaviors seen in the wild. Encouraging species-typical behaviors is the primary goal of environmental enrichment and also helps meet the four typical goals of zoos: education, conservation, recreation, and research. Constructing a gum-feeding device is easy and inexpensive, and can help to encourage naturalistic behaviors in captivity. Practical application of ecological data in captive contexts is just one way physical anthropologists can contribute to the conservation and welfare of some of our closest living relatives. Unfortunately, primate researchers and primate caretakers do not currently appear to be successfully communicating with each other. Wild primate researchers must begin

playing an active role in researching, designing, and implementing environmental enrichment programs, so that captive gum feeding behaviors resemble gum feeding behaviors seen in the wild. Gum feeding will benefit from the sharing of information regarding preferred gum forms, feeding devices, and feeding schedules. This study shows that exudate-based enrichment, although inexpensive and easy to implement, is not being utilized to its full potential. However, as environmental enrichment is a new and developing field, the prospects for improving gum-based enrichment are very promising.

APPENDIX A

ZOO CONTACTS AND RESPONDENTS

Zoos that completed the survey:
Attica Zoological Park, Greece
Banham Zoo, England
Belfast Zoo, Northern Ireland
Black Pine Animal Park, USA
Blackpool Zoo, England
Boras Djurpark, Sweden
Bronx Zoo, USA
Chester Zoo, England
Cleveland Metroparks Zoo, USA
Columbian Park Zoo, USA
Dickerson Park Zoo, USA
Dublin Zoo, Republic of Ireland
Durrell Wildlife Conservation Trust, England
Edinburgh Zoo, Scotland
Elmwood Park Zoo, USA
Hamilton Zoo, New Zealand
Hogle Zoo, USA
Hong Kong Zoo, Hong Kong
Houston Zoo, USA
Indianapolis Zoo, USA
Isle of Wight Zoo, England
Louisville Zoo, USA
Marwell Zoo, England
Milwaukee County Zoo, USA
Newquay Zoo, England
North Carolina Zoological Park, USA
Northeastern Wisconsin Zoo, USA
Oakland Zoo, USA
Paignton Zoo, England
Palm Beach Zoo, USA
Perth Zoo, Australia
Philadelphia Zoo, USA
Phoenix Zoo, USA
San Antonio Zoo, USA
San Diego Zoo, USA
Singapore Zoo, Singapore
Smithsonian Natl., USA
St. Louis Zoo, USA
Tarongo Zoo, Australia
The Santa Ana Zoo at Prentice Park, USA
The Zoo of Northwest Florida, USA
Twycross Zoo, England
Woodland Park Zoo, USA
Zoo Atlanta, USA
Zoo Landau in der Pfalz, Germany
Zoo Montana, USA

Zoos that were contacted, but did not complete the survey:
Alexandria Zoological Park, USA
Apenheul Primate Park, Netherlands
Audubon Zoo, USA
Aukland Zoo, New Zealand
Austin Zoo, USA
Binghamton Zoo, USA
Birmingham Zoo, USA
Brandywine Zoo, USA
Brevard Zoo, USA
Brisbane's Alma Park Zoo, Australia
Bristol Zoo Gardens, England
Brookfield Zoo, USA
Buffalo Zoo, USA
Capron Park Zoo, USA

Central Florida Zoo, USA
Chattanooga Zoo, USA
Cheyenne Mountain Zoo, USA
Colchester Zoo, England
Connecticut's Beardsley Zoo, USA
Dakota Zoo, USA
Dallas Zoo, USA
Denver Zoo, USA
Drusillas Park, England
Dudley Zoo, England
Erie Zoo, USA
Fort Wayne Children's Zoo, USA
Granby Zoo, Canada
Honolulu Zoo, USA
Jacksonville Zoo, USA
Kansas City Zoo, USA
Knoxville Zoo, USA
Kolner Zoo, Germany
London Zoo, England
Los Angeles Zoo, USA
Lincoln Park Zoo, USA
Lupa Zoo, USA
Magnetic Hill Zoo, Canada
Manor House Wildlife Animal Park, Wales
Minnesota Zoo, USA
Minsk Zoo, Belarus
Mogo Zoo, Australia
Monkey World, England
Mvog Betsi Zoo, Cameroon
Naples Zoo, USA
Niabi Zoo, USA
Oklahoma City Zoo, USA
Oregon Zoo, USA
Peoria Zoo, USA
Pittsburgh Zoo, USA
Potawatomi Zoo, USA
Roger Williams Park Zoo, USA
Roosevelt Park Zoo, USA
Rosamond Gifford Zoo at Burnet Park, USA
San Francisco Zoo, USA
Santa Barbara Zoo, USA
Scovill Zoo, USA
Sedgwick County Zoo, USA
Seneca Park Zoo, USA
Sierra Safari Zoo, USA
Southwick's Zoo, USA
Sunset Zoo, USA
Tallinn Zoo, Estonia
Tampa's Lowry Park Zoo, USA
The Jackson Zoo, USA
Tierpark Hellabrunn, Germany
Toronto Zoo, Canada
Uganda Wildlife Education Center, Uganda
Utica Zoo, USA
Vancouver Zoo, Canada
Vienna Zoo, Austria
Washington Park Zoo, USA
Wellington Zoo, New Zealand
Whipsnade Zoo, England
Woburn Safari Park, England
Zoo Boise, USA
Zoo Negara, Malaysia
Zoo Peru, Peru

APPENDIX B

SURVEY INTRODUCTION AND QUESTIONS

Gummivorous Primate Enrichment Survey

The purpose of this survey is to determine how zoos handle the diet and enrichment for primates that eat exudates in the wild. An exudate is the sap or gum produced by a tree. The groups included in this survey are patas monkeys, marmosets, tamarins, vervets, baboons, and bushbabies.

The final goal of this project is to produce a resource in which keepers of these primates can read about feeding and enrichment techniques used in zoos around the world.

When responding to questions regarding the design/build of enrichment devices and exudate recipes, please be as specific as possible. This information will be particularly valuable to those wishing to further develop enrichment programs for gummivorous primates.

It is not necessary to repeat descriptions of devices if they are the same for multiple groups. If you have repetitive information, you may type "see above," or any other equivalent phrase.

Please enter "N/A," "not sure," or an equivalent phrase when necessary.

The survey will take from 15 minutes to one hour to complete, depending upon the number of primate groups for which you answer questions and the amount of detail you provide in your responses.

Part 1: Patas Monkeys

1. Does your zoo house patas monkeys (*Erythrocebus patas*)? If no, please skip to Part 2: Marmosets.

2. Please indicate how many patas monkeys of each sex and age your zoo houses.

3. What foods do your patas monkeys eat? Please include quantities, frequencies, and be as specific as possible. (Ex: 2 lbs. bananas per day, 1 lb. mealworms per week, 24 oz. primate chow once per day.)

4. Do you separate any of the patas monkeys during feeding time?

5. Do the patas monkeys eat indoors, outdoors, or both?

6. What types of feeding enrichment does the zoo offer the patas monkeys? Please place an "X" next to all that apply.
a. None
b. Puzzle Feeders
c. Dispersed Food
d. Hidden Food
e. Extractive Foraging Devices
f. Other (please provide specification in the next question)

7. Please describe in as much detail as possible the feeding enrichment for the patas monkeys. Include the design/build of enrichment devices, techniques used, and the foods offered.

8. Do all the patas monkeys receive the same amount of enrichment? If no, please elaborate.

9. With patas monkeys, how do you handle aggression brought on by enrichment?

10. Does the zoo feed gum in any form to the patas monkeys (i.e. gum arabic, tree sap, exudates)? Please place an "X" next to all that apply.
a. No, do not feed gum
b. Yes, powdered
c. Yes, collected from a tree (unaltered)
d. Yes, solid gummy foods such as candy
e. Yes, other (please specify)

11. Is the gum for the patas monkeys by itself or mixed with other ingredients?

12. With what other ingredients is the gum for the patas monkeys mixed? Please provide recipes if applicable and available.

13. What time of day do you feed gum to your patas monkeys? Please place an "X" next to all that apply.
a. Morning (5:00am - 11:59am)
b. Afternoon (12:00pm - 4:59pm)
c. Evening (5:00pm - 8:59pm)
d. Night (9:00pm - 4:59am)

14. Please describe how the gum is presented to the patas monkeys (for example: in a puzzle feeder in liquid or gel form, in a bowl as gummy candies, in an extractive foraging device). Please be as specific as possible.

Part 2: Marmosets

1. Does your zoo house marmosets? If no, please skip to Part 3: Tamarins.

2. What species of marmosets does the zoo house? How many animals of each species? Please include sex and approximate age.

3. If your zoo houses multiple species of marmosets, are they housed together or separately? Please describe housing/exhibit arrangement.

4. What foods do your marmosets eat? Please include quantities and be as specific as possible. (Ex: 1 lb. grasshoppers per day, 24 oz. canned marmoset diet twice per day.)

5. Do you separate any of the marmosets during feeding time?

6. Do the marmosets eat indoors, outdoors, or both?

7. What types of feeding enrichment does the zoo offer the marmosets? Please place an "X" next to all that apply.
a. None
b. Puzzle Feeders
c. Dispersed Food
d. Hidden Food
e. Extractive Foraging Devices
f. Other (please provide specification in the next question)

8. Please describe in as much detail as possible the feeding enrichment for the marmosets. Include the design/build of enrichment devices, techniques used, and the foods offered.

9. Do all the marmosets receive the same amount of enrichment? If no, please elaborate.

10. With marmosets, how do you handle aggression brought on by enrichment?

11. Does the zoo feed gum in any form to the marmosets (i.e. gum arabic, tree sap, exudates)? Please place an "X" next to all that apply.
a. No, do not feed gum
b. Yes, powdered
c. Yes, collected from a tree (unaltered)
d. Yes, solid gummy foods such as candy
e. Yes, other (please specify)

12. Is the gum for the marmosets by itself or mixed with other ingredients?

13. With what other ingredients is the gum for the marmosets mixed? Please provide recipes if applicable and available.

14. What time of day do you feed gum to your marmosets? Please place an "X" next to all that apply.
a. Morning (5:00am - 11:59am)
b. Afternoon (12:00pm - 4:59pm)
c. Evening (5:00pm - 8:59pm)
d. Night (9:00pm - 4:59am)

15. Please describe how the gum is presented to the marmosets (for example: in a puzzle feeder in liquid or gel form, in a bowl as gummy candies, in an extractive foraging device). Please be as specific as possible.

Part 3: Tamarins

1. Does your zoo house tamarins? If no, please skip to Part 4: Vervets.

2. What species of tamarins does the zoo house? How many animals of each species? Please include sex and approximate age.

3. If your zoo houses multiple species of tamarins, are they housed together or separately? Please describe housing/exhibit arrangement.

4. What foods do your tamarins eat? Please include quantities and be as specific as possible. (Ex: 1 lb. mealworms per day, 3 lb. apples once per week, 24 oz. New World monkey chow per day.)

5. Do you separate any of the tamarins during feeding time?

6. Do the tamarins eat indoors, outdoors, or both?

7. What types of feeding enrichment does the zoo offer the tamarins? Please place an "X" next to all that apply.
a. None
b. Puzzle Feeders
c. Dispersed Food
d. Hidden Food
e. Extractive Foraging Devices
f. Other (please provide specification in the next question)

8. Please describe in as much detail as possible the feeding enrichment for the tamarins. Include the design/build of enrichment devices, techniques used, and the foods offered.

9. Do all the tamarins receive the same amount of enrichment? If no, please elaborate.

10. With tamarins, how do you handle aggression brought on by enrichment?

11. Does the zoo feed gum in any form to the tamarins (i.e. gum arabic, tree sap, exudates)? Please place an "X" next to all that apply.
a. No, do not feed gum
b. Yes, powdered
c. Yes, collected from a tree (unaltered)
d. Yes, solid gummy foods such as candy
e. Yes, other (please specify)

12. Is the gum for the tamarins by itself or mixed with other ingredients?

13. With what other ingredients is the gum for the tamarins mixed? Please provide recipes if applicable and available.

14. What time of day do you feed gum to your tamarins? Please place an "X" next to all that apply.
a. Morning (5:00am - 11:59am)
b. Afternoon (12:00pm - 4:59pm)
c. Evening (5:00pm - 8:59pm)
d. Night (9:00pm - 4:59am)

15. Please describe how the gum is presented to the tamarins (For example: in a puzzle feeder in liquid or gel form, in a bowl as gummy candies, in an extractive foraging device). Please be as specific as possible.

Part 4: Vervets

1. Does your zoo house vervet monkeys (grivet, savannah, tantalus, or green monkeys)? If no, please skip to Part 5: Baboons.

2. What species of vervets does the zoo house? How many animals of each species? Please include sex and approximate age.

3. If your zoo houses multiple species of vervets, are they housed together or separately? Please describe housing/exhibit arrangement.

4. What foods do your vervets eat? Please include quantities and be as specific as possible. (Ex: 1 lb. apples per day, 24 oz. primate biscuits twice per day.)

5. Do you separate any of the vervets during feeding time?

6. Do the vervets eat indoors, outdoors, or both?

7. What types of feeding enrichment does the zoo offer the vervets? Please place an “X” next to all that apply.
a. None
b. Puzzle Feeders
c. Dispersed Food
d. Hidden Food
e. Extractive Foraging Devices
f. Other (please provide specification in the next question)

8. Please describe in as much detail as possible the feeding enrichment for the vervets. Include the design/build of enrichment devices, techniques used, and the foods offered.

9. Do all the vervets receive the same amount of enrichment? If no, please elaborate.

10. With vervets, how do you handle aggression brought on by enrichment?

11. Does the zoo feed gum in any form to the vervets (i.e. gum arabic, tree sap, exudates)? Please place an “X” next to all that apply.
a. No, do not feed gum
b. Yes, powdered
c. Yes, collected from a tree (unaltered)
d. Yes, solid gummy foods such as candy
e. Yes, other (please specify)

12. Is the gum for the vervets by itself or mixed with other ingredients?

13. With what other ingredients is the gum for the vervets mixed? Please provide recipes if applicable and available.

14. What time of day do you feed gum to your vervets? Please place an “X” next to all that apply.
a. Morning (5:00am - 11:59am)
b. Afternoon (12:00pm - 4:59pm)
c. Evening (5:00pm - 8:59pm)
d. Night (9:00pm - 4:59am)

15. Please describe how the gum is presented to the vervets (For example: in a puzzle feeder in liquid or gel form, in a bowl as gummy candies, in an extractive foraging device). Please be as specific as possible.

Part 5: Baboons

1. Does your zoo house baboons (excluding geladas)? If no, please skip to Part 6: Galagos.

2. What species of baboons does the zoo house? How many animals of each species? Please include sex and approximate age.

3. If your zoo houses multiple species of baboons, are they housed together or separately? Please describe housing/exhibit arrangement.

4. What foods do your baboons eat? Please include quantities and be as specific as possible. (Ex: 1 lb. apples per day, 24 oz. monkey chow once per day.)

5. Do you separate any of the baboons during feeding time?

6. Do the baboons eat indoors, outdoors, or both?

7. What types of feeding enrichment does the zoo offer the baboons? Please place an "X" next to all that apply.
a. None
b. Puzzle Feeders
c. Dispersed Food
d. Hidden Food
e. Extractive Foraging Devices
f. Other (please provide specification in the next question)

8. Please describe in as much detail as possible the feeding enrichment for the baboons. Include the design/build of enrichment devices, techniques used, and the foods offered.

9. Do all the baboons receive the same amount of enrichment? If no, please elaborate.

10. With baboons, how do you handle aggression brought on by enrichment?

11. Does the zoo feed gum in any form to the baboons (i.e. gum arabic, tree sap, exudates)? Please place an "X" next to all that apply.
a. No, do not feed gum
b. Yes, powdered
c. Yes, collected from a tree (unaltered)
d. Yes, solid gummy foods such as candy
e. Yes, other (please specify)

12. Is the gum for the baboons by itself or mixed with other ingredients?

13. With what other ingredients is the gum for the baboons mixed? Please provide recipes if applicable and available.

14. What time of day do you feed gum to your baboons? Please place an “X” next to all that apply.
a. Morning (5:00am - 11:59am)
b. Afternoon (12:00pm - 4:59pm)
c. Evening (5:00pm - 8:59pm)
d. Night (9:00pm - 4:59am)

15. Please describe how the gum is presented to the baboons (For example: in a puzzle feeder in liquid or gel form, in a bowl as gummy candies, in an extractive foraging device). Please be as specific as possible.

Part 6: Galagos

1. Does your zoo house galagos (bushbabies)? If no, please skip to Part 7: General Questions.

2. What species of galagos does the zoo house? How many animals of each species? Please include sex and approximate age.

3. If your zoo houses multiple species of galagos, are they housed together or separately? Please describe housing/exhibit arrangement.

4. What foods do your galagos eat? Please include quantities and be as specific as possible. (Ex: 5 oz. mealworms per day, 12 oz. monkey chow per day.)

5. Do you separate any of the galagos during feeding time?

6. Do the galagos eat indoors, outdoors, or both?

7. Are the galagos on a reversed light cycle?

8. What times do the lights switch for the galagos? How?

9. What types of feeding enrichment does the zoo offer the galagos? Please place an “X” next to all that apply.
a. None
b. Puzzle Feeders
c. Dispersed Food
d. Hidden Food
e. Extractive Foraging Devices
f. Other (please provide specification in the next question)

10. Please describe in as much detail as possible the feeding enrichment for the galagos. Include the design/build of enrichment devices, techniques used, and the foods offered.

11. Do all the galagos receive the same amount of enrichment? If no, please elaborate.

12. With galagos, how do you handle aggression brought on by enrichment?

13. Does the zoo feed gum in any form to the galagos (i.e. gum arabic, tree sap, exudates)? Please place an "X" next to all that apply.
a. No, do not feed gum
b. Yes, powdered
c. Yes, collected from a tree (unaltered)
d. Yes, solid gummy foods such as candy
e. Yes, other (please specify)

14. Is the gum for the galagos by itself or mixed with other ingredients?

15. With what other ingredients is the gum for the galagos mixed? Please provide recipes if applicable and available.

16. What time of day do you feed gum to your galagos? Please place an "X" next to all that apply.
a. Morning (5:00am - 11:59am)
b. Afternoon (12:00pm - 4:59pm)
c. Evening (5:00pm - 8:59pm)
d. Night (9:00pm - 4:59am)

17. Please describe how the gum is presented to the galagos (For example: in a puzzle feeder in liquid or gel form, in a bowl as gummy candies, in an extractive foraging device). Please be as specific as possible.

Part 7: General Questions

1. What is your position at the zoo?

2. Do you feel the enrichment is beneficial? Please explain. (This question includes all groups that are part of this survey: patas monkeys, marmosets, tamarins, vervets, baboons, and bushbabies.)

3. Do you have photos, sketches, or detailed text descriptions you are willing to share? If yes, I will contact you for more information.

4. Does your zoo want a copy of the finished report? If yes, please provide an e-mail address or physical address.

5. If your zoo has a well-developed enrichment program, or simply some interesting techniques or devices, I am interested in experiencing them in person in the summer of 2008. I would sincerely appreciate any offers for zoo visits and am willing to complete any necessary proposal forms. May I visit your zoo? If yes, whom should I contact?

End Of Survey

Thank you very much for your participation in this survey. I estimate the project will be finished in the spring of 2009.
Please contact me directly for any additional information or comments.
Hillary Huber, Texas State University- San Marcos, hh1124@txstate.edu

APPENDIX C

GUM FEEDING TECHNIQUES FOR EACH SPECIES OF MARMOSET, TAMARIN, AND GALAGO

	No. zoos that house	**No. that feed gum**	**Form of gum**			**Method of gum feeding**						**Gum feeding time**		
			Pow-dered	Crys-tallized	Raw	Dish	For-aging device	Log feeder	Spread on exhibit material	Fresh bran-ches	Injected into gouged holes	Morn-ing	After-noon	Eve-ning
Calli-mico goeldi	4	3	3	0	0	1	0	2	2	0	0	2	2	1
Calli-thrix argen-tata	5	5	4	2	2	4	2	0	1	0	0	0	5	0
C. geoff-royi	10	9	8	2	3	5	1	4	1	0	0	2	8	1
C. jacc-hus	3	3	3	1	0	1	1	1	1	0	0	1	3	0
C. kuhlii	2	1	1	0	0	0	1	0	1	0	0	0	1	0
C. peni-cillata	3	3	3	1	0	1	1	1	1	0	0	1	3	0
Ceb-uella pyg-maea	22	19	16	3	2	8	5	4	5	1	1	9	12	2
Leon-topith-ecus chryso-melas	14	8	7	2	0	3	1	4	2	0	N/A	2	7	0

APPENDIX C continued

	No. zoos that house	**No. that feed gum**	**Form of gum**			**Method of gum feeding**						**Gum feeding time**		
			Pow-dered	Crys-tallized	Raw	Dish	For-aging device	Log feeder	Spread on exhibit material	Fresh bran-ches	Injected into gouged holes	Morn-ing	After-noon	Eve-ning
L. chryso-pygus	3	2	2	0	0	2	0	0	0	0	N/A	0	2	0
L. ros-alia	23	12	12	1	1	4	3	5	3	0	N/A	3	10	0
Sag-uinus bicolor	11	7	6	1	1	4	2	3	1	0	N/A	1	6	0
S. fusci-collis	2	1	1	0	0	0	0	1	1	0	N/A	0	1	0
S. geoff-royi	2	2	2	0	0	0	1	1	1	0	N/A	1	1	0
S. imper-ator	14	12	11	2	1	6	5	4	2	0	N/A	4	10	0
S. labi-atus	2	1	1	0	0	0	0	1	0	0	N/A	0	1	0
S. midas	4	3	3	1	0	1	1	1	1	0	N/A	0	3	0
S. mystax	2	2	2	0	0	0	1	1	1	0	N/A	0	2	0
S. oedi-pus	25	14	13	2	0	5	3	6	4	0	N/A	4	12	0
Galago moholi	2	1	1	0	0	0	1	0	1	0	N/A	0	1	0
G. senega-lensis	2	2	0	2	0	1	0	1	0	0	N/A	1	1	0
Oto-lemur spp.	1	0	0	0	0	0	0	0	0	0	N/A	0	0	0

APPENDIX C continued

	No. zoos that house	**No. that feed gum**	**Form of gum**			**Method of gum feeding**						**Gum feeding time**		
			Pow-dered	Crys-tallized	Raw	Dish	For-aging device	Log feeder	Spread on exhibit material	Fresh bran-ches	Injected into gouged holes	Morn-ing	After-noon	Eve-ning
Un-speci-fied galago	1	0	0	0	0	0	0	0	0	0	N/A	0	0	0

APPENDIX D

CONSTRUCTING A SIMPLE LOG FEEDER

1. Start with a cylindrical piece of wood about 10 cm in diameter and 30 - 40 cm in length. For best results with callitrichids and galagos, select a piece of wood with a diameter twice the size of the primates for which it is being used. This will mimic the natural habitat and allow use of the tegulae for clinging. Decide whether vertical or horizontal hanging is preferred. Horizontal hanging feeders (see figure below) encourage play behavior and exercise, as they can be used as a swing and the animals can access the gum by stretching from the branch from which the feeder is hung. Vertical feeders (see figure below) encourage naturalistic behavior, as many species of callitrichids use their claw-like nails (tegulae) for clinging to the trunks of trees during exudate feeding (Garber 1987; Garber 1992; Garber & Leigh 2001).
2. For a horizontal feeder, drill gum reservoirs only into the surface of the wood that will face up. For a vertical feeder, gum reservoirs may be drilled over the entire surface. Drill holes about 2 cm deep, 2 cm in diameter, and 4 cm apart.
3. Prepare the feeder for hanging by attaching clamps, ropes, and/or eye screws. One technique is to drill one or more holes all the way through the wood and thread rope through the holes. Alternatively, attach one or more eye screws and thread

4. rope through the heads of the screws. The feeder can be hung using the rope itself, or with a clipping device (e.g. a carabiner).
5. For a more complex design that encourages marmosets to gouge to retrieve the gum, see McGrew et al. (1986). The internal reservoir design described reportedly replicates the full range of gum-foraging patterns seen in wild marmosets.

Horizontal Log Feeder

Vertical Log Feeder

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Hillary Fries Huber was born in Helotes, Texas on December 29, 1980. In August 1999, she began her undergraduate education at the University of Texas at Austin, where she majored in music. After a year and a half, Hillary transferred to the University of Texas at San Antonio (UTSA). Hillary gained experience working with captive primates as a volunteer in the enrichment department at the Southwest National Primate Research Center. She graduated with a Bachelor of Arts in Anthropology from UTSA in May 2004. After several years of regular, boring employment, Hillary decided to begin graduate school. She entered the anthropology program at Texas State University-San Marcos in August 2007, focusing on physical anthropology and primatology. During graduate school, she was employed as a Graduate Instructional Assistant for two courses: History of Anthropological Thought and Introduction to Physical Anthropology. She received her Master of Arts in Anthropology from Texas State University-San Marcos in May 2009.

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