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RESEARCH ARTICLE

Behavioral and Physiologic Responses to Environmental Enrichment in the Maned Wolf (*Chrysocyon brachyurus*)

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The ex situ population of maned wolves is not self-sustaining due to poor reproduction, caused primarily by parental incompetence. Studies have shown that environmental enrichment can promote natural parental behaviors in zoo animals. The objective of this study was to determine the effects of environmental enrichment on behavioral and physiological responses of maned wolves. During an 8-week experimental period, daily behavior observations and fecal sample collection were conducted on four adult wolves (2.2) individually housed in environments without enrichment. After 2 weeks, the wolves were chronologically provided with 2-week intervals of hiding dead mice around the exhibit, no enrichment, and introduction of boomer balls. Responses of the wolves to enrichment were assessed based on activity levels and exploratory rates, as well as the level of corticoid metabolites in fecal samples collected daily throughout the study period. Providing wolves with environmental enrichment significantly increased exploratory behaviors ($P<0.05$), especially when mice were hidden in the enclosure. Fecal corticoid concentrations were increased during periods of enrichment in males ($P<0.05$), but not in females. Overall, there were no correlations between behavioral responses to enrichment and fecal corticoid levels. Behavioral results suggest that environmental enrichment elicits positive effects on the behavior of captive maned wolves. There is evidence suggesting that providing animals with ability to forage for food is a more effective enrichment strategy than introducing objects. There is need for a longer term study to determine the impact of environmental enrichment in this species. Zoo Biol 0:1–13, 2007. © 2007 Wiley-Liss, Inc.

Keywords: maned wolf; enrichment; behavior response; corticoids

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INTRODUCTION

The maned wolf (*Chrysocyon brachyurus*) is a Neotropical canid that lives in habitats being severely compromised by agricultural development. Listed as 'near threatened' on the IUCN Red List [IUCN, 2004], the species is native to South American grasslands and found primarily in Brazil, also ranging into areas of Bolivia, Argentina, Paraguay, Peru, and possibly Uruguay [Dietz, 1984; Rodden et al., 2004]. Despite its flagship status, the number of maned wolves living in nature is unknown, and wild populations are increasingly at risk due to habitat loss to agriculture [Dietz, 1984; Rodden et al., 2004]. A Population and Habitat Viability Assessment held in Brazil in 2005 estimated there may be ~20,000 wolves living in the wild; the vast majority are in Brazil.

Because wild populations have declined substantially, maintaining a self-sustaining, viable captive population is vital. Maned wolves maintained in zoos have three functions: 1) ambassadors for the disappearing grasslands; 2) a research resource; and 3) a hedge against a catastrophe affecting the remaining wild population. Although breeding of maned wolves in captivity has improved during the past few years (Rodden, unpublished), neonatal mortality remains high [International Studbook, 2003], due to abandonment and cannibalism of young [Maia and Gouveia, 2002]. This may be caused by lack of pup rearing experience and inappropriate housing environments such as insufficient den sites [Wielebnowski, 1998]. It has been suggested that parental care behavior in zoo animals can be easily disrupted even at low levels of stress when other aspects of reproduction are normal [Shepherdson et al., 1998; Wielebnowski, 1998]. Providing captive animals with appropriate environmental enrichment can promote natural parental behaviors, which in turn enhances reproductive success in captive individuals [Shepherdson et al., 1998].

Overwhelming evidence exists to support the benefits of enrichment for reducing abnormal or stereotypic behaviors, particularly in captive primates and carnivores [Shepherdson et al., 1998]. Enrichment has been shown to increase activity levels and normal exploratory behaviors, while reducing abnormal pacing and hiding in bears and felids [Forthman et al., 1992; Carlstead et al., 1993a,b; Shepherdson et al., 1993; Wielebnowski et al., 2002a,b; Bashaw et al., 2003].

Environmental enrichment includes a wide range of activities aiming to enhance the environment of captive animals. These activities can be divided into two major categories aiming to provide: 1) opportunities for exploration and play; or 2) control over the environment [Markowitz and Aday, 1998; Mench, 1998; Shepherdson and Carlstead, 2000]. Exploration is an important component of most species life strategies [Mench, 1998]. Animals need to continuously explore the environment to stay aware of food and water sources, shelters, trails, predators, hazards, territory intruders, and potential mates. Animals in captivity are typically maintained in static environments and have limited opportunities to explore [Mench, 1998]. Novel objects, scents, and exhibit changes are techniques used to stimulate exploratory behavior. However, these tactics can become static themselves, only requiring a few minutes to investigate in typically small enclosures [Hare and Worley, 1995; Mench, 1998].

Control or choice is the other major component missing in the lives of captive animals [Markowitz and Aday, 1998; Shepherdson and Carlstead, 2000]. Free-roaming animals make choices daily about when and where to forage, what to eat, whom to interact with and where to sleep. All of these choices are limited for animals in the strictly controlled environments of captivity. Studies have suggested that this lack of control leads to most stereotypic behaviors [Shepherdson et al., 1998; Mellen and MacPhee, 2001]. Control is given back to captive animals by providing choices and opportunities to "work" (e.g., multiple shelters and puzzle feeders), thus providing empowerment for the animal. The complexity of this enrichment strategy is limited only by human creativity, and seems to offer the best opportunity to elicit natural and complex behavioral repertoires [Markowitz and Aday, 1998].

Formulation of effective environmental enrichment strategies is dependent on species, age, sex, social structure and individual variations [Mench, 1998]. The principal goal of this study was to identify an appropriate environmental enrichment regimen for captive maned wolves. This study was designed to determine whether: 1) enrichment can improve the behavioral repertoire of captive maned wolves; 2) changes in behavior are reflected in fecal corticoid levels; and 3) there are differences in behavioral and physiologic responses to empowerment and exploration enrichment strategies. In this study, improving the behavioral repertoire is defined as an increase in natural behaviors and a decrease in stereotypic behaviors or apathy. In this study, we compare two types of enrichment: 1) boomer balls were used, referred to as novel objects [Poole, 1998] in attempt to increase exploratory opportunity; and 2) food hiding was used to provide wolves the opportunity to search for food, referred to as empowerment [Markowitz and Aday, 1998].

MATERIALS AND METHODS

Animals

Experimental subjects were four adult maned wolves; two females (Wolves L and R) and two males (Wolves C and Z) maintained at the Conservation and Research Center (CRC) in Front Royal, Virginia. All wolves were born and raised in captivity; Wolves R and Z were hand-raised, whereas Wolves C and L were parent-reared. Each wolf was housed alone, but in similar enclosures. Enclosures consisted of a large fenced in yard ($10 \times 30\,m$) and an outdoor den with access to a heated building ($3 \times 5\,m$). The CRC is not open to the public; thus, wolves were not exposed to visitors. Three of four wolves (1.2) had successfully produced and raised at least one litter. All four wolves were fed the same diet of dog chow, fruit and mice, and were cared for by the same primary keeper. This study was conducted from February–April, the non-breeding season for this species. All procedures were reviewed and approved by the CRC Institutional Animal Care and Use Committee.

Experimental Design

The experimental schedule was as follows: behavioral observations were conducted and fecal samples collected daily for: 1) 2 weeks of "no" enrichment; 2) 2 weeks of "hiding mice" enrichment; 3) 2 weeks of "no" enrichment; and 4) 2 weeks of "boomer balls" enrichment. The first 2-week period of no enrichment served as a baseline control. The second period with no enrichment was intended to avoid interactions between the two enrichment periods.

The "hiding mice" enrichment consisted of the primary keeper hiding a varied number of dead mice, which are preferred food items of maned wolves, around the enclosure each day in different locations, providing unpredictability. The wolves were accustomed to their primary keeper, and thus were not distracted by human odor. Other food items (i.e., dog chow and fruit) also were provided to the animals at the same time; thus, the wolves have choices between searching for mice or eating offered food. Boomer balls of various sizes and shapes (a total of 5 balls were used) were also placed in the enclosure by the primary keeper. All wolves had been living at CRC for at least 4 years, and had never been exposed to balls of any kind during this time. A different sized and shaped ball was placed in an enclosure each day, always in a different location and removed at the end of each observation period. After each session, the balls were washed with mild detergent to remove animal scent. Care was taken to ensure that exposure to the same sized (or shaped) ball was not repeated on 2 consecutive days for the same individual, and that each wolf was exposed to each ball the same number of times. All enrichment items were placed in the enclosures at the same time each day (i.e., in the morning after feeding).

Behavior Observations

Quantitative behavioral data were collected daily on each wolf in 30-min observation sessions in the morning after feeding, by the same observer using the focal sampling method [Martin and Bateson, 1986]. Behaviors of interest were predetermined and divided into two major categories: activity levels and exploratory characteristics. Activity levels were determined by recording the behavioral state every 30 sec. When the wolves were sitting, lying down or sleeping, the activity level was recorded as "inactive." When the wolves were grooming, sniff, standing, walking, pacing, or scent marking, the activity level was recorded as "active." Exploratory behavior levels were determined by recording all events determined to best represent natural and desired behaviors (sniff object or ground, paw or dig at ground and scent mark). According to Rodden et al. [1996], scent marking behavior includes repeatedly rubbing of the cheek or neck on the surface of the object, urinating or defecating; however, in the present study, only urination was counted as a scent marking behavior. Daily activity rates were calculated by dividing times that wolves were active by the total observation period (i.e., 30 min). Exploratory rates were calculated by dividing the total number of behavioral events by the total observation period.

Analysis of Fecal Corticoid Metabolites

Fecal samples from each wolf were obtained daily throughout the experimental period. The samples were placed in Ziploc bags and labeled with the subject's name and date of collection. Samples were stored at −20°C until processing and analysis. Fecal samples were collected in the morning and were assumed to have been deposited the previous day. An ACTH challenge conducted on the gray wolf (*Canis lupus*) showed a 16–20 hr lag time for peak glucocorticoid concentrations in fecal material [Sands and Creel, 2004]. A study in which radiolabeled testosterone was infused into a maned wolf showed that all isotope excretion occurred within 16 hr [Velloso, 1996]. However, it has been shown that excretion rate of steroid hormones varies greatly among individuals within the same species as well as among species [Palme et al., 1996]. Therefore, fecal corticoid level for a given day was correlated with a 2-day average of behavior data observed before the day of fecal collections.

Samples were dried in a lyophilizer, then 0.2 g of fecal powder was boiled for 20 min in 90% ethanol and 10% distilled water followed by centrifugation at $500 \times g$ for 20 min. The first supernatant was recovered and the pellet re-dissolved in 5 ml of 90% ethanol and centrifuged at $500 \times g$ for 15 min. The second supernatant was recovered and combined with first one; both were dried down under air and re-dissolved in 1 ml of methanol (100%). Average fecal extraction efficiency was 87% with a coefficient of variation $<10\%$.

Corticoid metabolites were quantified by enzyme immunoassay (EIA) [Munro et al., 1991] using an anti-cortisol antiserum (R4866; 1:85,000 dilutions) obtained from Coralie Munro (University of California, Davis, CA). Before analysis, fecal extracts were diluted in phosphate buffered saline (1:500). Serial dilutions of pooled fecal extracts produced displacement curves parallel to those of the cortisol standard curve. Inter- and intra-assay variations were $<10\%$. Assay sensitivity was 3.9 pg/well.

Statistical Analysis

Because of the small animal number ($n = 4$) and highly variable responses across wolves, data analysis and interpretation were done separately for each individual.

Daily activity and exploratory rates were calculated for each wolf during each period of 1) ''no'' enrichment; 2) ''empowerment'' (i.e., hiding mice); and 3) ''novel object'' (i.e., boomer balls) and analyzed for differences using Wilcoxon tests.

Fecal corticoid concentrations are reported as mean $\pm$ standard error (SEM). Overall, baseline, peak corticoid concentration, and coefficient of variation (CV) for each enrichment period for each individual were calculated. Baseline values were calculated by an iterative process, whereby high values exceeding the mean + 1.5 standard deviation (SD) were excluded. The average was then recalculated, and the elimination process repeated until no values exceeded the mean + 1.5 SD. A peak average included only values >1.5 SD. Before further analysis, all data were transformed using the common logarithm, $\log^{10}$, to adjust for a skewed, non-normal distribution, and then tested for normality using Sigma Stat 3.0 (SPSS Inc., Chicago, IL). Comparisons of mean fecal corticoid concentrations among treatments within the same individual were conducted using analysis of variance followed by Duncan's multiple range tests. Spearman-rank correlation analyses were conducted to determine the correlation between activity/explore rates and fecal corticoid metabolites. Differences were considered significant at $P<0.05$.

RESULTS

Behavioral Response to Environment Enrichment

Figure 1 shows activity and exploratory rates of four maned wolves after one of two types of enrichment or no enrichment. In all wolves, there were no significant differences in behavioral responses between the two ''no enrichment'' periods ($P>0.05$); thus, data were combined and compared to those of 'hiding mice'' and boomer balls' periods. Behavioral responses to enrichment seemed to differ among wolves. There were no differences in activity rates of Wolf L among treatments (Fig. 1A), although exploratory rate significantly increased when enrichment was

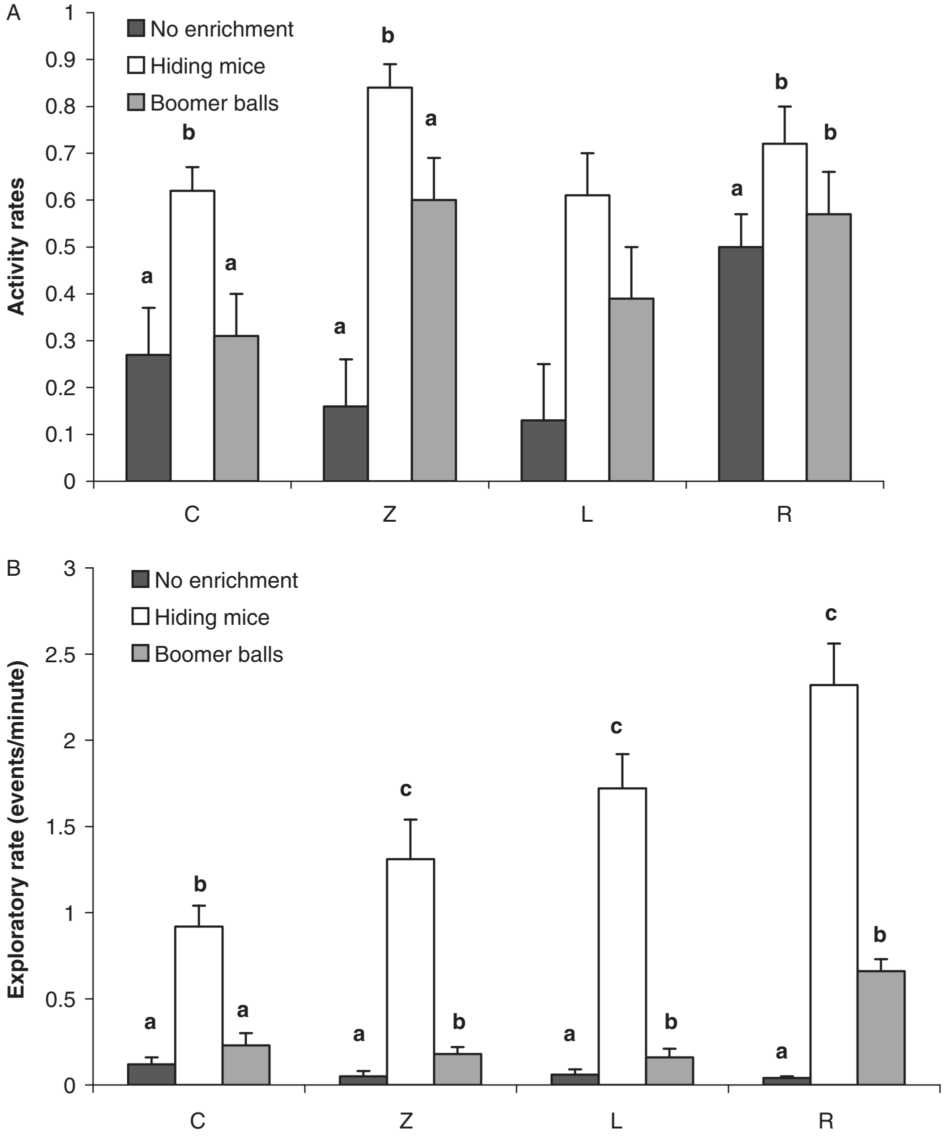

Fig. 1. Activity (**A**) and exploratory (**B**) rates of four maned wolves (C, Z, L, and R) without enrichment or when enrichment was provided by hiding mice or introducing boomer balls. Different letters within the same wolf indicate significant differences ($P<0.05$).

provided ($P<0.05$, Fig. 1B). For the remaining wolves, providing them with enrichment, especially hiding mice resulted in overall positive behavioral changes (i.e., increased activity or exploratory rates, $P<0.05$) (Fig. 1A,B). Exploratory rates during the period when mice were hidden around the enclosure were significantly higher than when boomer balls were introduced ($P<0.05$). Interestingly, only male wolves, especially Wolf Z, significantly responded to the boomer balls. A significant increase in the rate of scent marking was observed in Wolf Z when a ball was provided ($P<0.01$, Fig. 2).

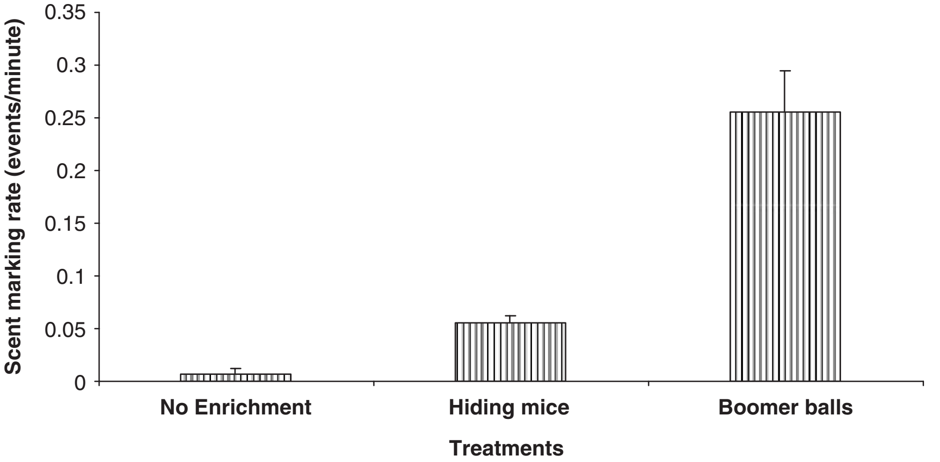

Fig. 2. Rate of scent marking when Wolf Z was provided with no enrichment, hiding mice, or boomer balls.

Physiologic Response to Environmental Enrichment

Figure 3 shows profiles of fecal corticoid metabolites of the four wolves for the entire study. Inter-individual variation and patterns were high in overall mean fecal corticoid concentrations, regardless of the absence or presence and types of enrichment (Fig. 3, Table 1). Enrichment significantly affected peak and baseline levels of fecal corticoids in males ($P<0.05$), but not in females (Table 1). Overall, baseline, and peak levels of fecal corticoids were higher during "hiding mice" enrichment than during introduction of boomer balls ($P<0.01$). There was no correlation between behavioral responses and corticoid concentrations for any of the wolves evaluated.

DISCUSSION

This is the first study to quantitatively examine behavioral and physiologic responses of captive maned wolves to environmental enrichment. The enrichment approaches examined were introduction of boomer balls and hiding mice in the enclosure. It was found that: 1) there are individual and gender variations in behavioral and physiologic responses to different types of enrichment; 2) hiding mice in the enclosure was more effective at promoting positive behaviors than boomer balls; and 3) providing wolves with enriched environments promoted exploratory behavior.

Association of Zoos and Aquariums and Behavior Scientific Advisory Group defines environmental enrichment as a process (changes in structure or husbandry practices) for improving or enhancing a zoo animal's environment within the context of their behavioral biology and natural history [Daley and Linsey, 2002]. The goal of this dynamic process is to increase behavioral choices available to animals and to draw out species appropriate behaviors and abilities [Daley and Linsey, 2000]. However, types of environmental enrichment are sometimes chosen more for their

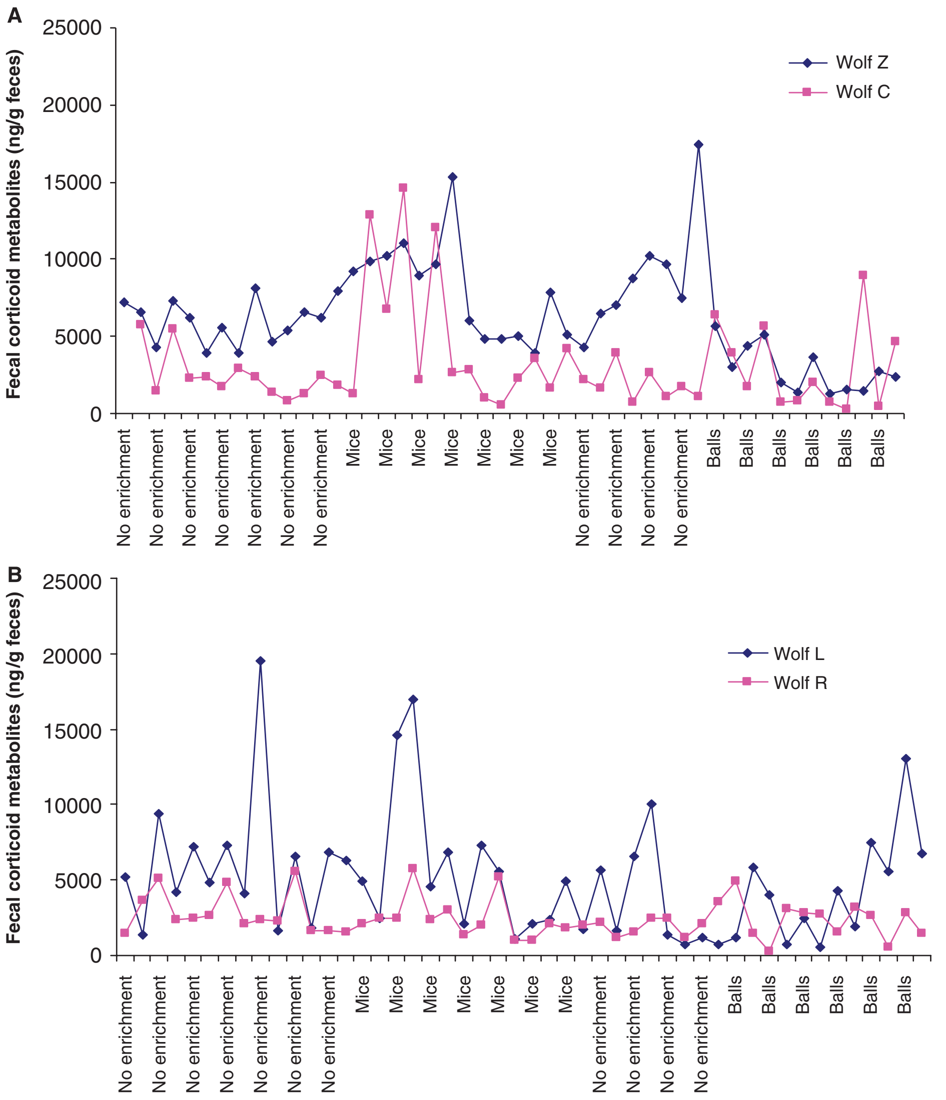

Fig. 3. Fecal corticoid metabolites of males (**A**) and females (**B**) maned wolves during the entire study period (i.e. 8 weeks).

durability, safety, availability, and cost than other properties that may be of greater benefit to the animals [Kreger et al., 1998]. A survey conducted in 1999 showed that most North American zoos holding maned wolves provided a variety of enrichment items. Fruit and mice were the two food items most frequently provided to wolves for enrichment, whereas tree trunks and long grasses were the most common furniture in maned wolf enclosures [Daley and Lindsey, 2000]. Although most institutions that responded to the survey indicated that wolves showed some level of interest in the enrichment items provided, quantitative responses were not measured.

In this study, providing enrichment to individually housed maned wolves increased both activity and exploratory rates. Exploratory rates seemed to be the

TABLE 1. Mean (±SEM) fecal corticoid concentrations of four maned wolves during enrichment and non-enrichment periods

Wolf	Gender	Fecal corticoids (μg/ml)	No enrichment	Boomer balls	Hiding mice	*P*-value
C	Male	Overall	2.3 ± 0.3	3.0 ± 0.8	4.9 ± 1.4	0.410
		Baseline	1.6 ± 0.1^{a}	1.3 ± 0.4^{a}	2.5 ± 0.5^{b}	0.045
		Peak	4.1 ± 0.5^{a}	7.0 ± 1.0^{b}	13.1 ± 0.7^{c}	<0.001
		CV (%)	61.2	94.3	100.5	
Z	Male	Overall	7.0 ± 0.5^{b}	2.9 ± 0.4^{a}	8.2 ± 0.9^{b}	<0.001
		Baseline	5.7 ± 0.3^{b}	1.4 ± 0.1^{a}	7.6 ± 0.7^{b}	0.002
		Peak	8.9 ± 0.4^{b}	3.6 ± 0.5^{a}	12.2 ± 1.6^{b}	<0.001
		CV (%)	23.6	52.8	39.3	
L	Female	Overall	5.0 ± 0.9	4.5 ± 1.0	5.8 ± 1.3	0.724
		Baseline	1.3 ± 3.2	3.4 ± 0.8	3.3 ± 0.5	0.881
		Peak	3.8 ± 0.5	8.5 ± 2.2	9.5 ± 2.4	0.382
		CV (%)	73.3	82.8	80.1	
R	Female	Overall	2.5 ± 0.2	2.2 ± 0.3	2.4 ± 0.3	0.572
		Baseline	2.0 ± 0.1	2.0 ± 0.3	1.8 ± 0.2	0.666
		Peak	4.8 ± 0.4	4.6 ± 0.8	3.7 ± 0.6	0.459
		CV (%)	49.1	58.0	59.1	

CV, coefficient of variance.
^{a,b,c}Different superscripts within the same row indicate significant differences.

better indicator of enrichment method effectiveness in this species. It has been shown in other species that increased exploratory behavior is a response of animals to environmental enrichment [Shepherdson et al., 1993; Carlstead and Shepherdson, 1994; Mench, 1998]. Many researchers consider an increased activity level as desirable for captive animals. However, the results of two studies on captive wolves (*Canis lupus baileyi* and *Canis lupus lupus*) are particularly noteworthy. Bernal and Packard [1997] compared wolves living in ''non-enriched'' vs. ''naturalistic'' enclosures. They found that wolves living in the ''non-enriched'' environments had higher activity and aggression levels. Frezard and Le Pape [2003] found that wolf packs living in larger, more ''naturalistic'' enclosures used less available space and spent more time resting. It is common knowledge that wolves in the wild spend a majority of their time resting, conserving energy until the next meal. Perhaps in captivity, a wolf that spends more time resting and is less active is a wolf behaving more ''naturally.'' In this case activity level may therefore not provide the best indicator for increased welfare (or well-being, and lower levels of stress). It would seem that increasing the overall behavioral repertoire may be a better index of welfare status in captive wolves than any single behavior.

Inter-individual variations in behavioral responses to environmental enrichment were consistent with those previously reported in other species [Kreger et al., 1998]. These variations are likely to due to individual gender differences and the conditions under which animals were reared (e.g., wild-caught vs. captive born or hand reared vs. parent-reared). In the present study, hiding mice elicited a behavioral response in both males and females. However, only male wolves responded to the boomer balls. A significant increase in the rate of scent marking was observed in Male Z when boomer balls were provided (Fig. 2); such behavior was not observed in the other wolves. It is worth noting that Male Z had been housed alone for most of his adult life, unlike others in the study, which have been paired for the majority of their adult life. This may explain his unique response to objects. Inter-individual variation in fecal corticoid concentrations was high and may in part reflect the inherent individual variability in response to environmental enrichment. Scent marking behavior of Male Z was associated with a temporary increase in 'arousal,' which may be beneficial or could have resulted from fear. An analysis of fecal corticoids during this enrichment period showed concentrations that were significantly lower than those during the "no enrichment" and "hiding mice" intervals. This suggests introducing boomer balls to this particular wolf may have been beneficial.

When enrichment strategies were compared, hiding mice seemed to result in more positive responses than introducing boomer balls with respect to increasing behavioral repertoire. This is not surprising, as several studies have shown that animals prefer to work for their food rather than be fed ad lib [Inglis and Fergusson, 1986; Kreger et al., 1998; Shepherdson et al., 1993; Shepherdson, 1998, Mellen and MacPhee, 2001]. Although objects placed in an animal's enclosure presented the opportunity to explore, the result was short-lived. Animals in the wild may spend an entire day or night exploring home ranges for any changes. However, in captivity the animal's home area is comparatively small and static. It only takes a few minutes to inspect a single object placed in the enclosure. As shown by observations in this study, the rate of exploratory behaviors was low for the boomer balls. Three of the four wolves inspected the object for <5 min, and then ignored it for the rest of the observation period.

By contrast, when mice were hidden around the enclosure, the rate of exploratory behaviors increased. Most interesting was that searching and foraging behaviors often continued for several minutes after all the mice had been located and consumed. Thus, the behavioral repertoire of natural behaviors was increased. The strongest evidence to support that hiding mice is more effective than boomer balls is that all four wolves in this study had significantly higher rates of exploratory behavior with the hidden mice than with the balls. Shepherdson et al. [1993] showed that minimizing predictability of food availability in small felids was an effective enrichment technique as it reduced stereotyped pacing and increased behavior diversity. It is the lack of opportunity to explore that may lead to stereotypic behaviors. It makes sense that having animals search for food gives them something to do, and engages them more thoroughly than simply placing novel objects in their space.

Studies in felids have shown that enrichment can decrease corticoid excretion rates, and potentially stress levels [Carlstead et al., 1993a,b; Wielebnowski et al., 2002a,b]. In the present study, there were large variations among individuals in physiological responses to enrichment; however, in general, hiding mice around the enclosure increased adrenal responses. It has been suggested that obtaining prey is a "good" stressor that stimulates the hypothalamic-pituitary adrenocortical axis [Moberg, 2000]. This may explain the increase in corticoid levels during the "hiding mice" enrichment period. Yet, the rise in corticoid levels could also suggest a negative effect of this type of enrichment. Although it seems animals were given a choice to search for food, it is unclear if such exploration is a positive or negative 'stressor.' A long-term evaluation to determine whether hiding mice elicits beneficial elevations in corticoid production is needed to identify how animals are affected by this enrichment method.

It has been shown in leopard cats that there is an inverse correlation between urinary corticoid levels and exploratory behavior [Carlstead et al., 1993b]. However, we did not find any correlations between fecal corticoid concentrations and exploratory behavior of any of the four maned wolves studied. This finding is consistent with that reported in the cheetah [Wielebnowski et al., 2002a] where fecal corticoid patterns were unrelated to behavior. The lack of agreement between these two studies may be due to species-specific variations (small vs. large cats) in responses to husbandry conditions. It is worth noting that earlier studies focused on the influence of husbandry conditions on behavior and adrenal activity, whereas the present study aimed to determine the impact of enrichment items on these responses. Thus, results obtained for the maned wolf may not be directly compared to those conducted in leopard cats and cheetahs.

It should be noted that each enrichment type was given to wolves for only 2 weeks, which would be insufficient to determine long-term effects. Wielebnowski et al. [2002a] studied adrenal activity of cheetahs subjected to "social stress" for 6 months. In that study, apparent changes in concentration of fecal corticoid were not observed until animals were housed as housed alone or paired for at least 2 months. Therefore, further investigations that include a longer period of enrichment are needed.

Interesting observations regarding behavior responses and corticoid levels were recorded in female Wolf R. This individual was hand-reared and was the only wolf to display stereotypic pacing. Behavioral responses of this individual to enrichment were not markedly different from the other three subjects, but assessment of fecal corticoid metabolites showed no physiologic response to enrichment. Corticoid concentrations remained stable and were consistently lower than those for the other wolves evaluated during the study period. There are two possible explanations for the lack of a corticoid response. It has been shown in domestic species that chronic stress can result in a shutdown of adrenal activity [James, 1979]. Given her tendency to pace, Wolf R may have experienced a stress-related suppression in normal corticoid production. Further studies using ACTH challenges may be necessary to determine whether this individual suffers from chronic stress. Another explanation is that the act of pacing may be a self-soothing activity. It has been reasonably argued that there is little evidence that pacing is harmful to an animal [Moberg, 1987; Mason, 1991]. In addition, pacing has been correlated with lower corticosteroid levels and adrenal gland weights [Mason, 1991]. It has been suggested recently that some stereotypic behaviors may actually improve welfare in poor environments [Mason and Latham, 2004]. Because stereotypic behaviors can arise from either poor or good conditions, and non-stereotyping individuals can have poor welfare, this pattern of behavior should not be used as a sole index of well being [Mason and Latham, 2004].

CONCLUSIONS

Based on the behavior data, we showed that environmental enrichment elicits positive effects on captive maned wolves. The results of this study provide evidence that hiding mice may be a more effective enrichment devise than providing wolves with boomer balls. Hiding mice increased adrenal activity significantly; however, further studies are needed to examine the nature of the relationship between corticoid production and enrichment in maned wolves. Behavioral observations were confined to a 30-min period daily for 2 weeks, only long enough to assess short-term effects. Further studies involving multiple sessions of behavioral observation with a longer duration of enrichment will be required to determine the long-term impact of enrichment on overall daily activity. Detailed study also is required to determine whether providing wolves with environmental enrichment would enhance reproductive success in this species.

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