Effects of Animal Management Changes on the Activity Budgets and Walking Rates of Zoo Elephants

Angela Dawn Mackey

University of Southern Mississippi

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EFFECTS OF ANIMAL MANAGEMENT CHANGES ON THE ACTIVITY BUDGETS AND WALKING RATES OF ZOO ELEPHANTS

by

Angela Dawn Mackey

A Dissertation
Submitted to the Graduate School
of The University of Southern Mississippi
in Partial Fulfillment of the Requirements
for the Degree of Doctor of Philosophy

August 2014
ABSTRACT

EFFECTS OF ANIMAL MANAGEMENT CHANGES ON THE ACTIVITY PATTERNS AND WALKING RATES OF ZOO ELEPHANTS

by Angela Dawn Mackey

August 2014

The current study aimed to assess the effects of two management strategies, weekly rototilling of the enclosure and the provision of unpredictable foraging opportunities, on the daily behavior of six elephants housed at the San Diego Zoo. Observations took place from January to June 2013 and were conducted throughout a 24-hour period. The study was divided into three phases, each two months in duration. During the first phase (baseline) no changes were made to the current management routine of the elephants. In Phase 2, rototilling of the elephant enclosures was increased from once monthly to once per week, while in Phase 3, the elephants were provided with unpredictable foraging opportunities during the day when keepers were present (weekly rototilling continued throughout this phase). Additionally, GPS technology was used to determine the daily walking distances and walking rates of the elephants in each phase of the study, while data loggers were used to determine number and duration of recumbent resting bouts. Activity budgets revealed that the elephants spent a majority of their time feeding ($M = 35\%, SD = 4.6\%)$ and resting ($M = 35\%, SD = 8.8\%)$, while behaviors such as locomotion ($M = 6.4\%, SD = 2.6\%)$ and exploration ($M = 4.8\%, SD = 1.9\%)$ were relatively low. Comparison of the activity budgets across study phases revealed that weekly rototilling did not have a significant effect on the elephants’ daily behavior, but unpredictable foraging opportunities resulted in a decrease in exploratory behavior.
(versus baseline) and an increase in stereotypic behavior (versus both baseline and rototilling alone). Average daily walking distances for the elephants ranged from 1.91 to 7.44 km, with walking rates between 0.08 km/hr and 0.31 km/hr, and did not differ significantly across management conditions. Overall, there were substantial individual differences in behavior across subjects in response to the changes in management routine, which may have implications for how these enrichment methods are implemented in the future.
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Approved:

Dr. Stan A. Kuczaj
Director

Dr. David Echevarria

Dr. Sheree Watson

Dr. John Harsh

Dr. Lance Miller

Dr. Maureen Ryan
Dean of the Graduate School

August 2014
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CHAPTER I

INTRODUCTION

The relationship between elephant and man is one that has persisted for several millennia. Rock paintings in India indicate that elephants may have been under human care as early as 6,000 B.C. (Lahiri Choudhury; cited in Bist, Cheeran, Choudhury, Barua, & Misra, 2002). Elephants were initially captured, tamed, and trained primarily for military purposes; however, in modern times they play an important role in a variety of activities, including logging and agricultural operations, wildlife tourism, and religious processions (Adams & Berg, 1980; Karunaratne & Ranawana, 1999; Sukumar, 2006). Elephants are also popular features of zoos and circuses worldwide (Clubb & Mason, 2002; Harris, Sherwin, & Harris, 2008).

The popularity of elephants in zoological facilities has led to increasing concern regarding the maintenance of elephants within these facilities. Stakeholders involved in this debate include zoo professionals, scientists, animal welfare/rights groups, the press, and the general public, all of which are ultimately interested in the welfare of zoo elephants (Gurusamy, Tribe, & Phillips, 2014; Soltis & Brown, 2010). While some stakeholders seek to end keeping elephants in zoos altogether (Clubb & Mason, 2002; Fowler, 2001), many interested parties are working to set higher standards of care for these animals (Clubb & Mason, 2002).

Zoos that house elephants are motivated, both ethically and practically, to provide for the physical and psychological well-being of their elephants (Soltis & Brown, 2010). Elephants serve an important role as a flagship species, generating public interest and financial support for the zoo as well as for conservation activities (Harris et al., 2008; Soltis & Brown, 2010; Walpole & Leader-Williams, 2002). This is particularly important
as Asian elephants \textit{in situ} are listed as endangered by the International Union for the Conservation of Nature (IUCN, 2012) while African elephants are listed as vulnerable (IUCN, 2012), primarily due to deforestation, human-elephant conflict, and poaching for ivory or meat (Choudhury, 1999; Hildebrandt et al., 2006; Wiese, 2000). However, the contributions zoo elephants make to conservation efforts are not simply of monetary value. Scientific research on populations within zoological facilities has not only led to a greater understanding of elephant biology and ecology, such as reproduction, communication, and nutrition, but has also allowed the development of numerous technologies relevant to field conservation (Smith & Hutchins, 2000). For example, zoo researchers have developed a way to extract DNA from ivory, which may allow investigators to track the geographic origin of ivory to determine if it comes from countries where ivory trade is illegal (Smith & Hutchins, 2000).

The main challenge zoos face in improving elephant management and husbandry standards is determining what changes are necessary. Historically, such decisions have been made based on personal opinion, past experience, or extrapolated from data on other species (Olson, 2002). In order for zoo professionals to make meaningful (i.e., biologically relevant) management changes, decisions must be based on empirical data (Dale, 2010; Hutchins, 2006; Mason & Veasey, 2010; Rothwell, Bercovitch, Andrews, & Anderson, 2011; Veasey, 2006), which, until recently, has been lacking. Studies that have examined zoo elephant behavior in a comprehensive manner are limited in number (e.g., Adams & Berg, 1980; Posta, Huber & Moore, 2013; Rees, 2009; Stoinski, Daniel, & Maple, 2000). Furthermore, few studies have conducted behavioral observations over a full 24-hour period, making it difficult to assess daily variations in behavior (Posta et al., 2013).
Elephants in Zoological Institutions

Within the past century, zoos have transitioned from being collections of animals on display for human curiosity to institutions for research, education, and conservation (Dale, 2010; Forthman Quick, 1984; Miller et al., 2004). This shift in philosophy, driven by an increase in society’s concern for the welfare of animals, as well as an awareness of the decline of wild animal populations, has resulted in a number of changes in the way zoos care for and manage their animals (Knowles, 2003). Animal enclosures have been renovated to increase their size and/or complexity (e.g., Chang, Forthman, & Maple, 1999; Goerke, Fleming, & Creel, 1987), environmental enrichment is routinely provided to promote species-typical behavior (e.g., Forthman et al., 1992; Weld & Erwin, 1990), and social groupings are managed to facilitate appropriate social interactions (e.g., Burks et al., 2004; Glatston, Geilvoet-Soeteman, Hora-Pecek, & van Hooff, 1984; Reinhardt, Houser, Eisele, & Champoux, 1987). These changes, along with improved nutrition and health care, have had a positive impact on zoo animal populations, with individuals of many species living longer and behaving more normally in modern zoos (Hutchins, 2006).

Despite such advances in animal care and management, facilities housing elephants still face major challenges in meeting the biological and behavioral needs of their charges (Veasey, 2006). One of the primary concerns for zoo professionals regarding elephant care and management is a lack of adequate exercise (Miller, Andrews, & Anderson, 2012). Free-ranging elephants have large home ranges (from ~200km$^2$ to ~11,000km$^2$; Douglas-Hamilton, 1998; Lindeque & Lindeque, 1991; Ntumi, van Aarde, Fairall, & de Boer, 2006; Thouless, 1995) and show great variability in the distance they travel on a daily basis, which depends on a number of factors including season (Leggett,
2009; Leggett, 2010; Theuerkauf & Ellenberg, 2000), distribution of resources (Leggett, 2006; Thomas, Holland, & Minot, 2011), and reproductive status (Slowtow & van Dyk, 2004). For example, African elephants living in the forests of Ivory Coast are reported to travel as much as 12 km/day (Merz, 1986), while African elephants in the arid desert of Namibia travel an average of 27.5 km/day (Viljoen, 1989). African elephants tend to have longer daily walking distances and higher walking rates than Asian elephants (see Leighty et al., 2009 for a review).

Free-ranging elephants also spend a majority (60-80%) of their day engaged in foraging activities, which includes locomotor movements as they search for food; digging/kicking at the soil as they feed on a variety of grasses, roots, herbs, and legumes; and pulling/ripping with the trunk in order to feed on fruit, tree bark, or foliage (Baskaran, Balasubramanian, Swaminathan, & Desai, 2010; Buckley, 2001; Karunaratne & Ranawana, 1999; Poole & Granli, 2009; Tchamba, & Seme, 1993). A number of studies on elephant feeding behavior report two peaks in feeding activity throughout the day—typically one in the morning and a larger peak just before dusk (Baskaran et al., 2010; Blake, Douglas-Hamilton, & Karesh, 2001; Guy, 1976; Joshi & Singh, 2008; Kalemera, 1987; McKay, 1973; Shannon, Page, Mackey, Duffy, & Slowtow, 2008; Wyatt & Eltringham, 1974).

Within a zoological setting, opportunities for elephants to engage in natural foraging and locomotor behaviors are limited. Exhibits cannot replicate either the size or the complexity of the natural environment (Hutchins, 2006; Mench & Kreger, 1996). This, coupled with the steady availability of resources, such as food and water, reduces the need and motivation of zoo elephants to travel long distances (Clubb & Mason, 2002; Leighty et al., 2009). Moreover, the feeding regimens imposed by animal care staff can
hinder the expression of natural foraging behaviors. In zoos where food is provided in large, concentrated amounts, the need for elephants to search for, manipulate, and process food items is nearly eliminated (Wiedenmayer, 1998).

Promoting appropriate levels of activity, in particular, locomotion, in zoo elephants is important for maintaining their health and welfare. During locomotion, the cushions of an elephant’s feet compress and relax with each step, helping to pump blood from the foot to the central venous system (Fowler, 2001). Walking and digging in yielding substrates serves to strengthen the tendons, ligaments, and muscles of the foot and leg, while also promoting an even wearing the footpad and toenails (Buckley, 2001; Fowler, 2001). Consequently, it has been suggested that adequate exercise may be central to the prevention or reduction of elephant health issues, including foot ailments, circulatory problems, joint diseases, and obesity (Clubb & Mason, 2002).

Increased activity levels may also promote elephant health and welfare by reducing the performance of aberrant behaviors that may result in negative health outcomes. One aberrant behavior of concern in zoo elephants is stereotypic swaying (Clubb & Mason, 2002). The repeated shifting of weight from side to side puts abnormal pressure on an elephant’s front feet and can lead to or exacerbate existing foot or joint problems (Roocroft & Oosterhuis, 2001; West, 2001). By filling an animal’s time budget with adequate opportunities to perform appropriate behaviors (e.g., locomotion, foraging), opportunities to engage in stereotypies will, in turn, be limited and the behavior should decrease (Veasey, 2006).

Recently, zoos have begun to address ways in which to improve the activity levels of their elephants. Some zoos have redesigned their outdoor elephant exhibits to increase their complexity and promote species-typical behaviors. Often, this is achieved by
providing natural substrates such as dirt, gravel, mud, and watering holes to allow for natural behaviors like dusting, wallowing, and bathing (American Zoo and Aquarium Association, 2011). Another way zoos promote activity in their elephants is through structured exercise and enrichment programs. In a survey of North American zoos, 81% of institutions reported having a structured exercise program for their elephants, while 95% reported having a structured enrichment program (Lewis, Shepherdson, Owens, & Keele, 2010). Zoos have also experimented with a number of food-related enrichments, such as food hiding, scatter-feeding, and feeder balls, each of which is intended to promote foraging behaviors and increase the amount of time spent actively searching for or processing food items (Haspeslagh, Stevens, Hanon, & Moons, 2011; Kinzley, 2006; Rees, 2009; Shepherdson, 1999; Wiedenmayer, 1998).

Current Study

The primary aim of the current study was to empirically examine the effect of two management routine changes on the behavior of elephants at the San Diego Zoo (SDZ), particularly with regard to daily activity budgets and walking rates. The first management change was an increase in the frequency of rototilling throughout the elephant enclosure to provide a softer substrate for the elephants. It was predicted that access to the softer substrate would result in increased performance of self-maintenance behaviors (e.g., dusting), longer recumbent rest periods, and increased locomotion throughout a full 24-hour period. The second management change was the provision of unpredictable foraging opportunities by allowing the elephants access to hanging hay nets at random times throughout the day. It was expected that the unpredictability of these opportunities would result in an increase in behaviors associated with foraging (i.e., feeding, exploring,
manipulating, and locomoting) and a decrease in stereotypic behavior, particularly during the daytime hours when this enrichment was taking place.

The current study also made use of modern technology, namely global positioning system (GPS) devices, to examine the daily walking rates of the elephants housed at SDZ. At this time, little is known regarding the daily walking rates of elephants in zoos, especially over a full 24-hour period. Of the few reports published in peer-reviewed journals, all have focused on the movement of the African elephant (*Loxodonta africana*; Leighty et al., 2009; Miller et al., 2012; Rothwell et al., 2011). The utilization of GPS devices in the current study provided much needed information on the walking distances and rates of Asian elephants in a zoological facility but also allowed for further assessment of the management changes on the elephants’ locomotor behavior.

Finally, the subjects in current study represented a unique demographic: older elephants (30+ years in age). Information on the behavior of this age class is becoming increasingly vital. With few young animals being added to zoological herds due to birth rates and high levels of infant mortality (Taylor & Poole, 1998; Wiese, 2000; Wiese & Willis, 2006), the median age of each herd will continue to get older and this particular age group will become increasingly common within zoos. Thus, the current study provided important information on the daily activity budgets, behavior patterns, and walking rates of this specific demographic.
CHAPTER II

METHODS

Subjects

The subjects for the current study were six unrelated elephants (aged 32-49) housed at the San Diego Zoo in San Diego, California (Table 1). The herd is mixed species, with four Asian elephants (*Elephas maximus*; one male, three female) and two female African elephants (*Loxodonta africana*). Each of the elephants was wild-born and later moved into a zoological facility.

Table 1

*Demographics of the Elephants Housed at San Diego Zoo*

<table>
<thead>
<tr>
<th>Elephant</th>
<th>Estimated age (yr)</th>
<th>Species</th>
<th>Reproductive history</th>
<th>Social Rank&lt;sup&gt;b&lt;/sup&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td>E1 ♂</td>
<td>46</td>
<td>Asian</td>
<td>Sire of 5 calves</td>
<td>Solitary bull</td>
</tr>
<tr>
<td>E2 ♀</td>
<td>48</td>
<td>Asian</td>
<td>Multiparous&lt;sup&gt;a&lt;/sup&gt;</td>
<td>1</td>
</tr>
<tr>
<td>E3 ♀</td>
<td>45</td>
<td>African</td>
<td>Nulliparous</td>
<td>2</td>
</tr>
<tr>
<td>E4 ♀</td>
<td>41</td>
<td>Asian</td>
<td>Nulliparous</td>
<td>3</td>
</tr>
<tr>
<td>E5 ♀</td>
<td>35</td>
<td>African</td>
<td>Nulliparous</td>
<td>5</td>
</tr>
<tr>
<td>E6 ♀</td>
<td>32</td>
<td>Asian</td>
<td>Nulliparous</td>
<td>4</td>
</tr>
</tbody>
</table>

<sup>a</sup> first calf aborted at 10 mos., second calf stillborn 1991

<sup>b</sup> social rank as determined by elephant care staff
Facility

The elephant habitat at the San Diego Zoo consists of an outdoor area made up of four interconnected enclosures and an “indoor” barn area (Figure 1). The outdoor area is approximately 9,700 m² of varying topography composed of various substrates (sand, dirt, humus soil) as well as two pools, which provide opportunities for bathing or swimming. The outdoor habitat also contains five “utilitrees” which provide shade, cool mist, foraging opportunities, heat (at night), and a place to scratch. The barn portion of the exhibit, known as the Elephant Care Center (ECC), is made up of several open-sided rooms and passageways, as well as one large completely indoor room with several observation windows. Two of the open-sided rooms, approximately 600 m², serve as staging areas where the elephants wait while the elephant care staff clean and stock the main exhibit with food or before being brought into one of the smaller stalls for husbandry purposes. During the study, each elephant was brought into the ECC at least once per day for husbandry training and routine care. The elephants were handled through protected contact, in which the elephant and keeper do not share the same space (i.e., there is a barrier between them).

All six elephants were housed in the outdoor area 24 hours a day unless medical needs required them to be kept in the ECC. The male elephant was housed by himself in the far enclosure (yard D), but was brought into the indoor room of the ECC during periods of low overnight temperatures or excessive rain. During the daytime all five females were housed together in the main enclosure and allowed to freely associate. The females entered the main enclosure (yard A) around 0930 and remained together until approximately 1600 when they were separated into their overnight social groups, which were variable, as were the enclosures in which they were housed. Each group was given
access to one of the staging areas in the ECC, which provided additional shelter and heat when necessary.

![Aerial view of elephant enclosures at the San Diego Zoo. A: main enclosure; B and C: alternative female yards; D: male enclosure; ECC: elephant care center. Image Google Earth, Landsat.]

The primary diet of the elephants was hay (Bermuda, Alfalfa, and Sudan); however, their diet was supplemented with herbivore pellet, vegetables, beet pulp, and variable browse. Upon arriving in the morning, the keepers provided each elephant with a flake of hay (~2.6kg). However, the majority of the elephants’ diet was provided during two main feeding times: in the morning after the staff cleaned the main exhibit areas (approximately 1000) and in the evening after the females were moved into their overnight social groupings (approximately 0430). Browse was typically added to the exhibit after the morning feeding and early in the afternoon, although the timing of this provision was variable. Foraging enrichments such as feeder balls, hay nets, and other manipulable feeders were regularly provided with an emphasis on increased processing and foraging time. Natural tree stumps were also added to the habitat on occasion, providing additional foraging opportunities.
Data Collection

Behavioral Data Collection

Behavioral data were collected over a six-month period from January to June 2013. Observations were conducted either from the perimeter of the enclosure or from an observation deck located on the upper floor of the ECC, depending upon the location and behavior of the focal subject. Each day of data collection consisted of three separate 1.5-hour observation periods separated by a 45-minute break to reduce observer fatigue. During each observation period, a 15-minute focal follow was conducted for each elephant, with the order of focal subjects being randomly determined in advance.

Behavioral data were collected on each focal animal using a data sheet (Appendix B), which consisted of a combination of scan sampling and all-occurrence data collection techniques (Altmann, 1974). At one-minute intervals, indicated by a stopwatch, the focal subject’s behavioral state was recorded. Additionally, throughout each one-minute interval, all occurrences of specific behavioral events were recorded for the duration of the observation period. An ethogram of behavioral states and events was created using operational definitions from previous research on zoo elephant behavior (Horback, 2012; Mueller, Dennis, Willis, Simone, & Lukas, 2013; Posta et al., 2013; Rees, 2009) and can be found in Appendix C.

In order to ensure data collection covered a full 24-hour period, observations were conducted in the following shifts: 0600-1200; 1200-1800; 1800-2400; 2400-0600. Two consecutive days of each shift were conducted before rotating to the next scheduled shift. Each rotation was separated by one day off and once all four shifts were covered, there was a three day break before the cycle began again. Over the course of the study, 96 days
of observations were conducted, resulting in 4,320 minutes (72 hours) of behavioral data for each elephant (1,440 minutes [24 hours] in each phase).

**GPS/Data Logger Recording**

On the second day of every 0600-1200 shift, ankle-mounted GPS recording devices (Qstarz BT-Q1000X [Taipei, Taiwan]) and data loggers (Onset HOBO® G Data Logger UA-004-64 [Pocasset, MA]) were placed on the foreleg of each elephant by the keepers. Elephants were desensitized to wearing the anklets through operant conditioning using positive reinforcement prior to the beginning of the study. The reliability and validity of the GPS devices for measuring walking rates in elephants has previously been established (see Miller et al., 2012). Once the anklet was secured on a subject, the time was recorded and the elephant wore the anklet for a minimum of 24 hours. Each GPS unit was set to record the elephant’s location every 5 seconds, while the data logger was set to record the elephant’s position on three axes once every minute in order to measure when the subject was standing versus lying. The GPS/data loggers were removed the following day by the elephant care staff and the data were downloaded for analysis.

**Elephant Management Changes**

The study was divided into three management phases, each two months in duration. An equal number of focal follows per elephant were conducted in each observation shift across all phases. Additionally, behavioral and GPS/data logger data were collected (as previously described) in a consistent manner across all phases. Phase 1 of the study provided baseline data on the elephants’ behavior and walking rates. During this phase, rototilling occurred in each enclosure at least once per month and feeding/enrichment was provided as described above. Phase 2 of the study involved increasing the frequency of rototilling so that all enclosures were tilled once each week.
rather than once a month. Rototilling occurred in the morning before the zoo opened and took place on the same day each week to provide consistency across observations. In Phase 3 of the study, the elephants were provided with unpredictable foraging opportunities. A hay bag was attached to each of the five utilitrees, connected to a built-in remote-controlled winch system that allowed the keepers to regulate the accessibility of the hay to the elephants. The hay bags were filled during the morning food setup (5.2kg each in yard A; 2.6 kg each in yards C and D) and each bag was lowered a maximum of five times on a pre-determined random schedule between 0900 and 1700. Each hay bag was accessible to the elephants for 15 minutes before once again being raised out of reach. A bag was not lowered if it no longer contained hay or if the elephants did not have access to the enclosure in which the bag was hanging. (Note: the increased rototilling schedule from Phase 2 also continued throughout Phase 3).

Data Analysis

Activity Budgets

An overall activity budget was calculated for each elephant by calculating the mean percentage of time engaged in each behavioral state per focal follow. Only one-minute scans in which the subject was in view were included in the analysis. A mean percentage of time engaged in each behavior was calculated for each elephant within each study phase in order to test for differences among the management conditions. Similarly, the rate of each behavioral event was calculated by dividing the total instances of an event by the number of minutes the subject was in view per focal follow. During the course of the study, there were situations in which the subject’s behavior may have been altered by factors other than the changes in management routines, such as being housed in an unusual enclosure (e.g., inside the ECC) or in a new social grouping. When these
events occurred, the subject’s behavior was compared to their average behavior within
the same timeframe under normal conditions (matched for phase of the study). If
significant differences in behavior were detected, that observation was removed from the
analysis to reduce potential confounds. This resulted in 77 observations (4.5% of total)
being excluded from the analysis (39 observations for E1, 14 observations for E3, and 6
observations for each of the other females).

**Behavioral Diversity**

In order to examine whether the diversity of behaviors exhibited by the elephants
changed across management conditions, a Shannon diversity index value was calculated
for both behavioral states and events within each focal follow. An average diversity index
was then calculated for each elephant in each management phase and compared across
phases. The Shannon diversity index is often used in ecology as a way of measuring
species diversity (Knapp et al., 2002; McNaughton & Wolf, 1973) but has been applied
to measure behavioral diversity in zoo animals (Shepherdson, Carlstead, Mellen, &
Seidensticker, 1993). It is calculated using the following formula in which \( P_i \) is the
proportion of time spent engaged in a particular (ith) behavior and \( R \) is equivalent to the
number of observed behaviors (states or events):

\[
H = \sum_{i=1}^{R} - (P_i \times \ln P_i)
\]

The value of \( H \) ranges from 0, indicating that all time observed was devoted to a single
behavior, to \( \ln R \), which indicates that each behavior was equally observed.
Walking Distances and Rates

Walking distances and rates were calculated by first determining a subset of valid latitude/longitude points and then summing the Euclidian distances between successive valid points (Leighty et al., 2009) over a 24-hour period. A GPS point was considered valid if it (1) had a horizontal displacement (HDOP) value less than 2.00, (2) had at least six satellites in view, and (3) was within the boundaries of the elephant exhibit when viewed in ArcMap 10.2 (Environmental Systems Research Institute [Redlands, CA]). Points that did not meet all three criteria were removed from the analysis. Additionally, because of potential inaccuracy, any points located within the “indoor” portion of the exhibit were also excluded. For the male elephant (E1), this meant that three days of data were not analyzed because he was housed in the indoor barn for a portion or all of the recording period (two days in Phase 1 of the study, one day in Phase 3).

The GPS device used for E1 did not record HDOP or satellite information for the first phase of the study. Once this error was discovered, a new GPS device was substituted for the remainder of the study. There was no difference between the distance travelled when all GPS points within the boundaries of the elephant exhibit were considered versus those when HDOP > 2.00 and satellite < 6 were removed ($t (7) = 1.51$, $p = .18$). Therefore, for this elephant, all GPS points located within the exhibit were used to determine walking distance across all phases of the study.

Statistical Analyses

Because of the small sample size, non-parametric tests using rank data were used for all statistical analyses. Differences among the three phases of the study were tested using a Friedman’s analysis of variance by ranks test, while differences between daytime and nighttime walking rates were tested using the Wilcoxon matched-pairs signed-rank
test. Alpha-level was set at $p < .05$. Post hoc tests were conducted on all significant
results using the Wilcoxon matched-pairs signed-rank test. No correction was made for
multiple comparisons as doing so would reduce the power of the test, which was already
low due to a small sample size, though this can inflate the Type I error rate.

*Inter- and Intra-observer Reliability*

Reliability testing was conducted using four hours of video (5.5% of total data)
collected prior to the beginning of the study. Each elephant was filmed for 10 minutes in
each observation shift (0600-1200, 1200-1800, 1800-2400, and 2400-0600). An attempt
was made to capture a wide range of behavioral contexts so that as many behavioral
states/events as possible were represented. All videos were coded prior to the beginning
of the study by the primary investigator and a second trained observer to assess inter-
observer reliability. In order to ensure data were collected consistently throughout the
study by the primary observer, intra-observer reliability was assessed through the
repeated coding of the videos. All videos were coded before the beginning of each phase
of the study and once at the conclusion of the study and compared. Agreement for
behavioral states was calculated as the percentage of scans in which the recorded state
was the same, while agreement for behavioral events was calculated between the
frequencies of recorded events using Pearson’s correlation. Both inter- and intra-observer
reliability were achieved at a level of 90% (states) and $r > .90, p < .01$ (events) or higher
throughout the study.
CHAPTER III
RESULTS

Activity Budgets

Overall, feeding ($M = 35.0\%, SD = 4.6\%$) and resting ($M = 35.0\%, SD = 8.8\%$) comprised the majority of the activity budget among all subjects, followed by locomotion ($M = 6.4\%, SD = 2.6\%$), exploration ($M = 4.8\%, SD = 1.9\%$), and keeper interaction ($M = 4.5\%, SD = 1.6\%$). On average, manipulation and self-maintenance behavior occurred at relatively low frequencies (2.3\%, $SD = 0.3\%$; and 2.1\%, $SD = 2.2\%$, respectively), as did behavior classified as “other” ($M = 0.7\%, SD = 0.2\%$). Stereotypic behavior accounted for an overall average of 7.7\% ($SD = 10.1\%$) of observed behavior.

The differences in the elephants’ behavioral states across management conditions are summarized in Table 2. As the male elephant was housed alone and had no opportunity to engage in social behaviors, this state was not analyzed. However, descriptive statistics were calculated for social behavior for the females and are presented. No difference was detected in the average percentage of time the elephants were engaged in feeding, locomotion, manipulation, resting, self-maintenance, keeper interaction, or behaviors recorded as “other” across phases of the study. Exploration was significantly different, with the elephants engaging in more exploratory behavior in Phase 1 than Phase 3 ($z = -2.20, p < .05$). Percent time spent engaged in stereotypic behavior also differed among the three phases of the study. Stereotypy was significantly higher in Phase 3 than both Phase 1 ($z = -2.02, p < .05$) and Phase 2 ($z = -2.02, p < .05$).

Although there was no significant difference in overall resting behavior across management conditions, it was predicted that rototilling would result in a larger percentage of time spent in recumbent rest. Resting behavior was classified as either
standing or recumbent rest and the average time spent in the recumbent position was calculated for each elephant within each management condition. No significant difference in time spent in recumbent rest was detected across phases of the study ($\chi^2 (2, N = 6) = 2.33, p = .31$).

The effect of unpredictable foraging opportunities in Phase 3 was expected to be most prevalent during the times the winch system was in operation (0900-1700); thus, the dataset was limited to this timeframe for further analysis. Friedman analysis of variance by ranks tests for each behavioral state showed no difference among phases: feed, $\chi^2 (2, N = 6) = 1.00, p = .61$; explore, $\chi^2 (2, N = 6) = 1.00, p = .61$; locomote, $\chi^2 (2, N = 6) = 2.33, p = .31$; manipulate, $\chi^2 (2, N = 6) = 4.00, p = .14$; rest, $\chi^2 (2, N = 6) = 0, p = 1.00$; self-maintenance, $\chi^2 (2, N = 6) = 1.00, p = .61$; stereotypy, $\chi^2 (2, N = 6) = 0.74, p = .69$; and other, $\chi^2 (2, N = 6) = 1.09, p = .58$. These results suggest that the significant differences in exploration and stereotypy that were present in the analysis of the full 24-hour period were occurring sometime other than between the hours of 0900 to 1700. Visual inspection of the data confirmed this, revealing that exploration was higher in Phase 1 from 2100 to 0800 (Figure 2), while stereotypy showed two periods where a difference between phases occurred— once between 0500 and 0800 and again between 1800 and 2100 (Figure 3).
### Table 2

**Results of Friedman Analysis of Variance by Rank Test for Behavioral States**

<table>
<thead>
<tr>
<th>Behavioral State</th>
<th>Phase 1</th>
<th></th>
<th>Phase 2</th>
<th></th>
<th>Phase 3</th>
<th>Mean (SD)</th>
<th>Mean rank</th>
<th>Phase 3</th>
<th>Mean (SD)</th>
<th>Mean rank</th>
<th>$\chi^2$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Feed</td>
<td>Mean (SD)</td>
<td>Mean rank</td>
<td>Mean (SD)</td>
<td>Mean rank</td>
<td>Mean (SD)</td>
<td>Mean rank</td>
<td></td>
<td>Mean (SD)</td>
<td>Mean rank</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Feed</td>
<td>35.08 (5.70)</td>
<td>1.83</td>
<td>34.16 (3.46)</td>
<td>1.83</td>
<td>35.93 (6.82)</td>
<td>2.33</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Explore</td>
<td>5.80 (1.88)</td>
<td>2.83</td>
<td>4.06 (1.70)</td>
<td>1.50</td>
<td>4.47 (2.30)</td>
<td>1.67</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>6.33*</td>
</tr>
<tr>
<td>Keeper Interaction</td>
<td>3.68 (1.60)</td>
<td>1.43</td>
<td>4.49 (1.05)</td>
<td>2.14</td>
<td>5.39 (1.37)</td>
<td>2.43</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>3.71</td>
</tr>
<tr>
<td>Locomote</td>
<td>6.55 (2.43)</td>
<td>2.00</td>
<td>6.09 (2.64)</td>
<td>1.50</td>
<td>6.75 (3.04)</td>
<td>2.50</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>3.00</td>
</tr>
<tr>
<td>Manipulate</td>
<td>2.33 (0.83)</td>
<td>2.00</td>
<td>2.81 (0.87)</td>
<td>2.50</td>
<td>1.78 (0.65)</td>
<td>1.50</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>3.00</td>
</tr>
<tr>
<td>Rest</td>
<td>34.46 (6.09)</td>
<td>2.00</td>
<td>38.11 (9.44)</td>
<td>2.67</td>
<td>31.61 (11.62)</td>
<td>1.33</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>5.33</td>
</tr>
<tr>
<td>Self-Maintenance</td>
<td>2.47 (1.99)</td>
<td>2.33</td>
<td>1.79 (2.39)</td>
<td>1.83</td>
<td>2.18 (2.23)</td>
<td>1.83</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>1.00</td>
</tr>
<tr>
<td>Social&lt;sup&gt;a&lt;/sup&gt;</td>
<td>2.30 (1.43)</td>
<td>--</td>
<td>1.75 (0.33)</td>
<td>--</td>
<td>1.89 (1.06)</td>
<td>--</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>--</td>
</tr>
<tr>
<td>Stereotypic</td>
<td>6.86 (9.66)</td>
<td>1.67</td>
<td>6.46 (9.03)</td>
<td>1.50</td>
<td>9.71 (13.06)</td>
<td>2.83</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>7.60*</td>
</tr>
<tr>
<td>Other</td>
<td>0.78 (0.33)</td>
<td>2.67</td>
<td>0.59 (0.26)</td>
<td>1.33</td>
<td>0.60 (0.24)</td>
<td>2.00</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>5.33</td>
</tr>
<tr>
<td>Out of View</td>
<td>2.59 (1.69)</td>
<td>1.79</td>
<td>3.70 (1.21)</td>
<td>2.5</td>
<td>2.86 (2.12)</td>
<td>1.71</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>2.74</td>
</tr>
</tbody>
</table>

<sup>a</sup>State was not included in the Friedman analysis. Mean values represent average of social behavior across females.

*Note.* *p* < .05
Figure 2. Mean frequency of exploratory behavior in Phase 1 and Phase 2. Exploratory behavior was significantly higher in Phase 1 between the hours of 2100 and 0800.

Figure 3. Mean frequency of stereotypic behavior across all three phases of the study. The frequency of stereotypic behavior was significantly higher in Phase 3 versus Phase 1 and Phase 2. These significant differences occurred from 0500-0800 and 1800-2100.
When the rate of behavioral events was examined, only two behaviors were significantly different among management conditions. The rate of object-directed behavior was higher in Phase 2 than Phase 3 (N = 6, z = -2.20, \( p < .05 \)) and dusting was higher in both Phase 1 (N = 6, z = -2.21, \( p < .05 \)) and Phase 3 (N = 6, z = -1.99, \( p < .05 \)). Further examination of the data revealed that the difference in object-directed behavior was primarily during the evening feeding between 1400 and 1800, while the difference in dusting occurred between 0500 and 1400. The rates of other events were consistent across study phases (Table 3).

**Individual differences in activity budgets**

There was considerable individual variability in regard to the overall activity budgets of the elephants (Figure 4). The highest frequencies of locomotion throughout the study were exhibited by the two African females (E4, 6.9% and E5, 11.0%), who also had the highest frequencies of exploration (E4, 6.8%; E5, 6.2%). Yet E5 had a 21% higher frequency of resting than E4 (37.5% versus 29.4%, respectively). The male elephant (E1) engaged in the lowest frequency of locomotion (3.2%) and exploration (1.8%) but had a very high frequency of feeding (35.7%) and resting (48.1%). In fact, more than 80% of his behavior consisted of those two behaviors alone. And while self-maintenance behavior had a fairly low frequency for a majority of the elephants, E3 was recorded in this state in 6.5% of all observations, more than 3.5 times higher than the elephant with the next highest frequency.
Table 3

*Results of Friedman Analysis of Variance by Rank Test for Behavioral Events*

<table>
<thead>
<tr>
<th>Behavioral Event</th>
<th>Phase 1</th>
<th></th>
<th>Phase 2</th>
<th></th>
<th>Phase 3</th>
<th></th>
<th>χ²</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Mean (SD)</td>
<td>Mean rank</td>
<td>Mean (SD)</td>
<td>Mean rank</td>
<td>Mean (SD)</td>
<td>Mean rank</td>
<td></td>
</tr>
<tr>
<td>Drink</td>
<td>0.022 (0.017)</td>
<td>1.83</td>
<td>0.026 (0.008)</td>
<td>2.17</td>
<td>0.027 (0.015)</td>
<td>2.00</td>
<td>0.33</td>
</tr>
<tr>
<td>Eliminate</td>
<td>0.013 (0.004)</td>
<td>1.67</td>
<td>0.016 (0.004)</td>
<td>2.00</td>
<td>0.022 (0.013)</td>
<td>2.33</td>
<td>1.33</td>
</tr>
<tr>
<td>Explore</td>
<td>0.170 (0.146)</td>
<td>2.00</td>
<td>0.155 (0.136)</td>
<td>1.50</td>
<td>0.194 (0.168)</td>
<td>2.50</td>
<td>3.00</td>
</tr>
<tr>
<td>Feed</td>
<td>0.957 (0.444)</td>
<td>2.50</td>
<td>0.959 (0.432)</td>
<td>1.83</td>
<td>0.953 (0.459)</td>
<td>1.67</td>
<td>2.33</td>
</tr>
<tr>
<td>Lie</td>
<td>0.001 (0.001)</td>
<td>1.50</td>
<td>0.002 (0.001)</td>
<td>2.17</td>
<td>0.003 (0.001)</td>
<td>2.33</td>
<td>2.33</td>
</tr>
<tr>
<td>Locomote</td>
<td>0.173 (0.081)</td>
<td>1.67</td>
<td>0.164 (0.060)</td>
<td>1.83</td>
<td>0.189 (0.086)</td>
<td>2.50</td>
<td>2.33</td>
</tr>
<tr>
<td>Dig</td>
<td>0.007 (0.012)</td>
<td>2.08</td>
<td>0.003 (0.003)</td>
<td>1.42</td>
<td>0.013 (0.016)</td>
<td>2.50</td>
<td>4.10</td>
</tr>
<tr>
<td>Dust</td>
<td>0.065 (0.050)</td>
<td>2.50</td>
<td>0.038 (0.027)</td>
<td>1.17</td>
<td>0.073 (0.070)</td>
<td>2.33</td>
<td>6.33*</td>
</tr>
<tr>
<td>Itch</td>
<td>0.109 (0.103)</td>
<td>2.17</td>
<td>0.099 (0.122)</td>
<td>2.00</td>
<td>0.116 (0.170)</td>
<td>1.83</td>
<td>0.33</td>
</tr>
<tr>
<td>Rub</td>
<td>0.027 (0.029)</td>
<td>2.25</td>
<td>0.019 (0.030)</td>
<td>1.83</td>
<td>0.017 (0.020)</td>
<td>1.92</td>
<td>0.636</td>
</tr>
<tr>
<td>Object-directed</td>
<td>0.078 (0.036)</td>
<td>1.67</td>
<td>0.119 (0.046)</td>
<td>2.83</td>
<td>0.066 (0.028)</td>
<td>1.50</td>
<td>6.33*</td>
</tr>
<tr>
<td>Stereotypy</td>
<td>0.062 (0.090)</td>
<td>2.17</td>
<td>0.050 (0.070)</td>
<td>1.33</td>
<td>0.073 (0.087)</td>
<td>2.50</td>
<td>5.20</td>
</tr>
</tbody>
</table>

*Note.* *p < .05*
Figure 4. Mean activity budgets of the six elephants at SDZ.
The behavioral state that showed the most variability across individuals was stereotypy. Only one elephant (E5) exhibited no stereotypy throughout the course of the study. Two female Asian elephants (E2 and E6) exhibited the highest frequencies of stereotypic behavior (25.0% and 16.6%, respectively). These elephants were observed swaying throughout the 24-hour period and in a number of different contexts (e.g., enclosure, social group, pre-/post-feeding), whereas the two elephants with the lowest frequencies of stereotypy (E3 and E5) engaged in the behavior primarily in the morning prior to the arrival of the keepers.

*Individual Differences in Response to Changes in Management Condition*

Individual differences in behavior were also apparent when examining the elephants’ behavioral responses to the changes in management conditions. The behavioral profiles of the elephants across the three phases of the study are presented in Figures 5-10.

*Subject E1.* The increase in rototilling occurring in Phase 2 had a noticeable effect on E1’s behavior. E1 showed a 25% increase in the frequency of resting behavior, spending more than 50% of his time resting in Phase 2, versus 40% in Phase 1. Conversely, E1 showed a decrease in active behaviors such as feeding (reduced by 21%), locomotion (reduced by 28%), and exploration (reduced by 75%) under the rototilling condition. When the unpredictable foraging enrichment was implemented in Phase 3, there were few changes in E1’s behavior. Manipulation underwent the largest change in frequency, decreasing by 50% (from 3.0% in Phase 2 to 1.5% in Phase 3). Stereotypic behavior also showed a considerable change, increasing by 35% (Phase 2: 2.7%; Phase 3: 4.1%).
Subject E2. For the most part, E2’s response during the increased rototilling in Phase 2 was similar to that of E1, with resting behavior increasing and most active behaviors decreasing (other than feeding, which increased). The behavioral changes exhibited by E2, however, were more moderate in size. Resting behavior increased by less than 10% from Phase 1 to Phase 2, while locomotion and stereotypy decreased by 15% and 11%, respectively. One of E2’s most notable behavioral changes was manipulation, which went from 0.7% in Phase 1 to 4.11% in Phase 2, an increase of 83%. Exploration also markedly changed, decreasing by 50%. During the unpredictable foraging enrichment in Phase 3, E2 showed much stronger changes in behavior, particularly in stereotypy and resting. E2 increased her frequency of stereotypy, engaging in this behavior more than 30% of the time she was observed, while only 17% of her time was spent resting (a decrease of nearly 40%). Exploration and social behavior also increased substantially (47% and 32%, respectively), returning to nearly the same levels observed in Phase 1.

Subject E3. Overall, E3 exhibited the fewest behavioral changes across the different management conditions. Between Phase 1 and Phase 2, E2’s behavior was fairly consistent; most behaviors that changed in Phase 2 did so by less than 7%. Only social behavior changed substantially in Phase 2 as compared to Phase 1, decreasing by more than 60% (from 4.7% in Phase 1 to 1.8% in Phase 2). E3’s behavior was also generally consistent when the unpredictable foraging enrichment was implemented in Phase 3. During this phase, the most notable changes in E3’s behavior were feeding and manipulation, which increased by 13% and 18%, respectively, and resting which decreased by 15% (from 42% in Phase 2 to 36% in Phase 3).
Subject E4. E4 exhibited a similar pattern to E1 in regard to her behavioral responses during increased rototilling in Phase 2. E4’s resting behavior increased by 22% (from 28% in Phase 1 to 37% in Phase 2), while active behaviors such as feeding, exploration, and locomotion decreased (by 4%, 25%, and 34%, respectively). These behavioral changes were reversed, however, when the unpredictable foraging enrichment was implemented in Phase 3. E4 increased her frequency of feeding by 13%, engaging in this behavior 47% of the time she was observed, while exploration and locomotion increased by 12% and 34%, respectively.

Subject E5. The changes in behavior exhibited by E5 in the rototilling condition were moderate. Compared to Phase 1, E5’s frequency of resting increased by 7.6% in Phase 2, while feeding decreased by 9.7%. The largest changes in E5’s behavior were exploration and self-maintenance, which decreased by 33% and 42%, respectively. Minimal changes were observed in locomotion and manipulation. When unpredictable foraging opportunities were provided in Phase 3, E5 increased her feeding behavior by nearly 20%, engaging in this behavior 40% of the time she was observed. Resting behavior decreased moderately, from 40% in Phase 2 to 35% in Phase 3. However, the most substantial change in E5’s behavior during the feeding enrichment was a decrease in manipulation, which decreased by 70%. The frequency of social behavior also decreased for this elephant in Phase 3, which dropped from 1.6% in Phase 2 to 0.7% in Phase 3, a decline of more than 50%.

Subject E6. The behavioral response of E6 during increased rototilling was, for the most part, opposite from that observed for the other elephants. Whereas the other elephants exhibited an increase in resting behavior from Phase 1 to Phase 2, E6’s resting
decreased (from 36% to 28%). E6 was also the only elephant to show an increase in locomotion and exploration in Phase 2 (by 32% and 12%, respectively) and a decrease in manipulation (by nearly 50%). Interestingly, when the unpredictable foraging enrichment was implemented, E6 showed a decrease in feeding (from 35% in Phase 2 to 28% in Phase 3), exploration (from 4.6% in Phase 2 to 2.8% in Phase 3), and manipulation (1.4% in Phase 2 to 0.9% in Phase 3)—behaviors that were expected to increase in this condition. As with E2, E6 exhibited a substantial change in stereotypy during Phase 3, increasing her frequency of this behavior from nearly 15% in Phase 2 to 22% in Phase 3.

**Figure 5.** Activity budget for E1 across all three phases of the study. Phase 1: baseline, Phase 2: rototilling, Phase 3: rototilling + unpredictable foraging. Asterisk (*) indicates that the lack of any time spent engaged in this behavior is due to this individual not having an opportunity to engage in the behavior rather than no observations of the behavior.
Figure 6. Activity budget for E2 across all three phases of the study. Phase 1: baseline, Phase 2: rototilling, Phase 3: rototilling + unpredictable foraging.

Figure 7. Activity budget for E3 across all three phases of the study. Phase 1: baseline, Phase 2: rototilling, Phase 3: rototilling + unpredictable foraging.
Figure 8. Activity budget for E4 across all three phases of the study. Phase 1: baseline, Phase 2: rototilling, Phase 3: rototilling + unpredictable foraging.

Figure 9. Activity budget for E5 across all three phases of the study. Phase 1: baseline, Phase 2: rototilling, Phase 3: rototilling + unpredictable foraging.
Daily Activity Patterns

The elephants were active for a majority of the 24-hour period (Figure 11). The elephants typically awoke between 0500 and 0600. From that time onward, their activity levels increased and remained high until approximately 2200, when there was a marked decrease in activity as the animals moved into their nightly resting period (2300-0500). Feeding was the primary behavior throughout the day (Figure 12a), peaking at times when food was provisioned by the elephant care staff (one flake of hay for each elephant around 7am, then two main feedings at approximately 1000 and 1700). When not occupied by feeding, the elephants spent time engaged in exploration, manipulation, self-maintenance, locomotion, socializing (females only) and stereotypy, with no single behavior dominating the elephants’ repertoire. Locomotion (Figure 12b) tended to
increase prior to the morning feeding and remained at a fairly steady level throughout the day until it began to decrease around 2100. Self-maintenance behavior (Figure 12c) was generally performed from just after rising in the morning until mid-afternoon (1300), at which point it decreased substantially. Manipulation (Figure 12d) was common just prior to the daily peaks in feeding (primarily manipulation of hay bags and other feeding enrichment items) but was also prevalent in the late evening (primarily manipulation of logs, rocks, and other non-food items). Interestingly, stereotypy (Figure 12e) and exploration (Figure 12f) followed a similar pattern throughout the day, peaking multiple times: in the morning between rising and the arrival of the keepers and following each of the daily feeding times (1300 and 1900).

Figure 11. Percentage of scans in which the elephants were active versus inactive. All behavioral states other than rest were considered active. Keeper interaction was excluded from the calculation as this state included both active (e.g., exercise session) and inactive (e.g. foot bath) behaviors.
Figure 12. Daily activity patterns of the elephants at SDZ. Mean frequencies are the average of frequency of behavior per observation across all six elephants: (a) feed, (b) locomote, (c) self-maintenance, (d) manipulate, (e) stereotypy, (f) explore.
Behavioral Diversity

Average behavioral diversity of states ranged from 0.34 to 0.69 (M = 0.60, SD = 0.13), while average behavioral diversity of events ranged from 0.50 to 1.07 (M = 0.91, SD = 0.03). There was no significant effect of management condition on the behavioral diversity values of either states ($\chi^2 (2, N = 6) = 1.00, p = .61$) or events ($\chi^2 (2, N = 6) = 2.33, p = .31$). The result was similar when the data set was limited to the 0900-1700 timeframe (states: $\chi^2 (2, N = 6) = 0.33, p = .85$; events: $\chi^2 (2, N = 6) = 2.33, p = .31$).

However, there was considerable individual variability when it came to changes in behavioral diversity across management conditions for both states (Figure 13) and events (Figure 14).

*Figure 13.* Mean behavioral diversity values for behavioral states across the phases of the study.
Figure 14. Mean behavioral diversity values for behavioral events across the phases of the study.

**Walking Rates**

In total, 288 hours of GPS data were analyzed for each of the female elephants and 216 hours for the male. Of the days for which GPS data were analyzed (i.e., excluding when the male was housed indoors), approximately 80% of the total GPS points recorded were considered valid and were included in the final dataset. Overall, the average daily distance traveled by all six elephants was 4.93 km ($SD = 1.99$), ranging from 1.92 km ($SD = 0.38$) to 7.44 km ($SD = 1.11$). The overall average walking rate of each elephant over the full 24-hour period ranged from 0.080 km/hr ($SD = 0.016$) to 0.379 km/hr ($SD = 0.048$), with an average of 0.245 km/hr ($SD = 0.106$) (Figure 15). The two female African elephants (E4 and E5) exhibited the highest rates of walking. The lowest rate of walking was exhibited by the male elephant (E1).

In order to determine if there were any diurnal differences in locomotor activity, daytime and nighttime walking rates were compared. GPS anklets were consistently placed on every elephant by 1000; therefore, daytime hours were considered 1000 to
Nighttime was considered 1700 to 2459 as most of the elephants’ activity had ended by this time. A Wilcoxon signed-rank test revealed elephants walked at significantly higher rates during the daytime hours than nighttime hours after the keepers had left for the day ($N = 6$, $Z = -1.99$, $p < .05$).

**Figure 15.** Mean walking rates of the six elephants at SDZ. Error bars represent standard deviation of the mean.

The average walking distances and rates within each phase of the study are summarized in Table 4. Management condition did not have a significant effect on the elephants’ walking rates; walking rates were similar across all three phases of the study ($\chi^2 (2, N = 6) = 1.33$, $p = .51$).

**Recumbent Resting**

Overall, the mean duration of recumbent rest was 233.6 minutes ($SD = 15.3$), with an average of 4.4 lying bouts per night ($SD = 0.52$). There were no significant differences in duration of recumbent rest ($\chi^2 (2, N = 6) = 0.33$, $p = .85$), number of lying
bouts ($\chi^2 (2, N = 6) = 1.85, p = .40$), average duration of lying bouts ($\chi^2 (2, N = 6) = 4.00, p = .14$), or time of onset of recumbent rest ($\chi^2 (2, N = 6) = 1.00, p = .61$) across the three management conditions.
Table 4

Average Walking Distances and Rates Across Phases of the Study

<table>
<thead>
<tr>
<th>Subject</th>
<th>Phase 1</th>
<th></th>
<th>Phase 2</th>
<th></th>
<th>Phase 3</th>
<th></th>
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<tbody>
<tr>
<td></td>
<td>Distance (SD)</td>
<td>Rate (SD)</td>
<td>Distance (SD)</td>
<td>Rate (SD)</td>
<td>Distance (SD)</td>
<td>Rate (SD)</td>
</tr>
<tr>
<td>E1</td>
<td>2.03 (0.09)</td>
<td>0.084 (0.004)</td>
<td>2.11 (0.46)</td>
<td>0.088 (0.019)</td>
<td>1.6 (0.15)</td>
<td>0.067 (0.006)</td>
</tr>
<tr>
<td>E2</td>
<td>4.47 (0.30)</td>
<td>0.246 (0.031)</td>
<td>5.34 (0.18)</td>
<td>0.252 (0.024)</td>
<td>4.50 (0.41)</td>
<td>0.226 (0.016)</td>
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<tr>
<td>E3</td>
<td>4.44 (1.10)</td>
<td>0.215 (0.059)</td>
<td>3.72 (0.93)</td>
<td>0.194 (0.053)</td>
<td>3.19 (0.77)</td>
<td>0.159 (0.036)</td>
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<tr>
<td>E4</td>
<td>6.66 (1.05)</td>
<td>0.345 (0.051)</td>
<td>6.46 (0.45)</td>
<td>0.323 (0.021)</td>
<td>6.99 (1.15)</td>
<td>0.330 (0.039)</td>
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<tr>
<td>E5</td>
<td>7.79 (1.11)</td>
<td>0.396 (0.051)</td>
<td>7.61 (0.84)</td>
<td>0.385 (0.041)</td>
<td>6.93 (1.41)</td>
<td>0.356 (0.055)</td>
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<tr>
<td>E6</td>
<td>4.59 (0.85)</td>
<td>0.237 (0.014)</td>
<td>5.49 (0.92)</td>
<td>0.269 (0.038)</td>
<td>4.80 (1.39)</td>
<td>0.238 (0.073)</td>
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<tr>
<td>Average</td>
<td>4.00 (2.01)</td>
<td>0.254 (0.109)</td>
<td>5.12 (1.96)</td>
<td>0.252 (0.103)</td>
<td>4.67 (2.11)</td>
<td>0.229 (0.107)</td>
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</tbody>
</table>
CHAPTER IV
DISCUSSION

The activity budgets of the elephants at SDZ revealed that a majority of the elephants’ time was spent engaged in feeding (34.5%) and resting (34.6%), with behaviors such as locomotion and exploration taking up much less of their day (6.4% and 4.8%, respectively). These activity budgets are markedly different from those reported for free-ranging elephants, particularly with regard to feeding and resting. Wild elephants spend 60-80% of their time feeding and only 1.4% resting (McKay, 1973; Wyatt & Eltringham, 1974). The difference in zoo elephant behavior in comparison to free-ranging elephants is likely due to the nature of the zoo environment. Zoo elephants are provided with food at regular intervals and in concentrated amounts. While this food meets their dietary needs, it is often provided in a manner that requires little searching and processing, resulting in decreased feeding durations (Morimura & Ueno, 1999; Shepherdson, 1999; Stoinski et al., 2000, Wiedenmeyer, 1998).

While the activity budgets in the current study differed from free-ranging elephants, the average walking distances and rates determined by GPS were consistent with those measured in free-ranging elephants. The average daily distance traveled by free-ranging African elephants is approximately 10 km (see Leighty et al., 2009 for review), with walking rates between 0.23 km/hr and 1.46 km/hr (Theuerkauf & Ellenberg, 2000; Wyatt & Eltringham, 1974). Free-ranging Asian elephants, on the other hand, have a shorter average daily walking distance and slower walking rates (0.01-1.5 km/hr; McKay, 1973). The African elephants in the current study walked an average of 7.1 km per day at a rate of 0.36 km/hr, while the Asian elephants walked an average of
3.9 km per day (rate 0.19 km/hr), which is within the range for wild elephants, albeit at the lower end.

The distances traveled by the elephants at SDZ were likely influenced by a number of factors, including keeper activity, social rank, enclosure size, and the subject’s health. Social rank, for example, may have inflated the distance traveled by E5, who was the newest member of the female social group and considered to be toward the bottom of the social hierarchy by the elephant care staff. When one of the higher ranked females approached E5 (particularly E4), she would often respond by quickly moving away. The male elephant (E1), on the other hand, was housed by himself and was thus not motivated to move in response to the presence of another elephant (e.g., resource competition, dominance). The limited movement of this elephant, then, may be related to the size of his enclosure or more likely, to age-related health issues, such as arthritis.

Effects of Management Conditions

*Rototilling*

At the group level, rototilling did not have a significant effect on the activity budgets of the elephants. There were individual differences, however, in the responses to this management condition. The most striking difference was in the behavior of E1, who drastically decreased the amount of time he spent locomoting, exploring, and feeding when the rototilling condition was implemented. E1 has arthritis in his hips, which affects his locomotion, often causing him to drag his hind feet as he walks. Thus, the depth of the soil after rototilling may have made locomotion too challenging for this individual, prompting him to walk less frequently and remain stationary for longer periods.

E6 was the only elephant to exhibit a decrease in resting behavior and an increase in locomotion during Phase 2. This behavioral change may be related to her low rank in
the social hierarchy. As many of the higher ranking females decreased their locomotion and exploration in Phase 2, E6 may have exploited the opportunity to move around the exhibit more freely. The increase in the locomotion of E6 may also have been, in part, a response to a difference in overnight social groupings between Phase 1 and Phase 2. E6 was never housed alone overnight with E5 except during the last week of Phase 1. However, throughout Phase 2 these two females were housed together in nearly 60% of the overnight observations. Although there were no overtly aggressive interactions between E6 and E5, E6 tended to avoid interactions with E5, maintaining a distance throughout the night.

The behavior of E3 and E4 during Phase 2 may have also been influenced by the changes in overnight social groupings. E3 and E6 were common social partners, spending much of their evening hours within 2 body lengths of one another. The move of E6 to a new social group likely resulted in fewer social interactions between these two (though they could still interact between the gates/fences separating the enclosures) and may partially explain the 60% decrease in E3’s social behavior. Additionally, on nights when E6 was housed with E5, E2 was added to the social group of E3 and E4. As E2 is the dominant female of the group, her presence may have affected how E3 and E4 spent their time at night.

*Unpredictable Foraging Opportunities*

The unpredictable foraging enrichment was expected to increase the activity levels of the elephants. In particular, foraging-related behaviors of the elephants (e.g., feeding, locomoting, manipulating, exploring) were expected to increase, while resting was expected to decrease. At the group level, however, few behavioral changes were
observed across management conditions. Significant effects were only observed in exploration and stereotypy.

A potential reason that the unpredictable foraging enrichment did not have the expected effect may be the schedule of its presentation. Hay bags were raised and lowered on a completely randomized schedule, providing the elephants with no chance of determining when or where they might have access to the food. If the elephants had had a chance to learn about the pattern of food delivery, they may have responded with an increase in foraging-related behaviors. For example, Watters, Miller, & Sullivan (2011) demonstrated the effect of intermediate levels of predictability on fennec fox behavior. In this study, Watters et al. (2011) varied the levels of certainty in the timing and location of food delivery. The highest level of behavioral diversity and lowest amount of inactivity was observed when the predictability of food was 25% or 75% versus 0% or 100%. Based on these results, the authors suggested that an intermediate amount of predictability in the environment is more stimulating for animals than either complete predictability or complete unpredictability.

Another possible explanation for the current results may be a low level of motivation for the elephants to adjust their behavior. First, the amount of food provided in the hay bags represented a very small portion of the elephants’ diet. Secondly, increased rototilling was still taking place during the feeding enrichment phase of the study. A majority of the elephants decreased their locomotion under the rototilling condition, but only one (E4) increased her locomotion substantially during the feeding enrichment. It is possible that the amount of food that could be obtained by moving when the hay bags were down was not worth the effort required to move in the softer substrate.
Two behaviors did change significantly in the presence of the unpredictable feeding enrichment: exploration and stereotypy. Exploratory behavior decreased when the rototilling condition was introduced but was not significantly less until the implementation of the unpredictable foraging enrichment. Interestingly, the drop in the frequency of exploration during Phase 3 was only present during the late evening and early morning hours (2100-0800). There was a corresponding increase in the frequency of stereotypy in the unpredictable foraging condition, which also occurred during the evening and early morning, and might partially explain this decrease in exploration; elephants that increased their stereotypy had less time in their activity budget for other behaviors.

The observed increase in stereotypy in Phase 3 was unexpected. Stereotypic behavior was prevalent in all phases of the study and peaked at three different periods in the day: early morning (0500-0800), midday (1200-1500), and evening (1800-2100). Yet the significant increase in stereotypy was limited to the morning and evening periods. The manner in which the enrichment in Phase 3 was implemented may explain this result. The hay bags attached to the utilitrees were only raised and lowered during the daytime when the keepers were present (0900-1700). Once the keepers left for the day, the hay bags (whether empty or full) remained in the raised position, inaccessible to the elephants, for the remainder of the night. (Note: during Phases 1 and 2, the elephants had access to hay bags or other manipulable feeders hanging from the utilitrees throughout the night). Thus, stereotypic behavior may have been triggered as a result of frustration/arousal from the presence, yet inaccessibility, of the hay bags. This may also account for the sharp increase in stereotypy in the morning (0500), which more than tripled from the baseline value. As the elephants lacked access to the hay bags throughout...
the night, it is possible that the first food delivered in the morning had a greater value, resulting in a higher frequency of anticipatory behavior.

Alternatively, the elephants may have been motivated to perform feeding-related behaviors, such as searching, manipulating, and processing—a need which could be satisfied by interacting with the hay bags and other manipulable items under normal conditions (such as in Phases 1 and 2). The absence of the opportunity to perform these internally motivated behaviors may have resulted in frustration and, in turn, higher levels of stereotypy (Swaisgood, 2007; Veasey, 2006). Support for this explanation comes from a number of studies that have shown that animals prefer to “work” for food, even when food is freely available (Coburn & Tarte, 1976; Coulton, Waran, & Young, 1997; Hughes, Duncan, & Brown, 1989; Inglis & Shepherd, 1994; Menzel, 1991; Reinhardt, 1994). Known as contrafreeloading, this phenomenon suggests that animals may have a motivation to perform specific behaviors (e.g., search, explore, process) and that the performance of the behaviors themselves may be just as reinforcing as the end goal (i.e., ingestion of food; Coburn & Tarte, 1976; Swaisgood, 2007). Providing zoo animals with opportunities to perform species-specific behaviors such as searching, digging, exploring, and processing has been shown to reduce stereotypic and aberrant behavior in a variety of zoo animals (Baker, 1997; Carlstead, Seidensticker, & Baldwin, 1991; Kastelein & Wiepkema, 1989; Shephedrson et al., 1993).

It is possible that extraneous variables unrelated to the management condition could have contributed to the increase in stereotypy in Phase 3. Phase 3 took place in May/June and therefore had a longer average photoperiod than Phase 1 and 2. In addition to longer periods of sunlight, the zoo was open later, especially toward the end of the study, and thus, the elephants were likely exposed to a larger number of visitors for a
longer period of time. While no studies have been conducted on the effect of zoo visitor presence on elephant behavior, such studies with primates have shown an increase in stereotypic behavior (Chamove, Hosey, & Schaetzel, 1988) and urinary cortisol levels (Davis, Schaffner, & Smith 2005), and a decrease in social behavior (Glatston et al., 1984) with larger numbers of zoo visitors.

Activity Patterns

The most interesting result in the analysis of the elephants’ activity patterns was regarding the daily patterns of stereotypy and exploration and their relationship to feeding. Stereotypy and exploration were strikingly similar in their occurrence throughout the day, each peaking at three different points: early morning before the keepers arrived, mid-day after the conclusion of the morning feeding, and late evening, after the conclusion of the evening feeding. The behavior of the elephants with the highest levels of stereotypy may have contributed to this result. E2, for instance, would often break a bout of stereotypic behavior by smelling the air or exploring the environment around her. However, the behavior of these individuals is not entirely responsible for the similarity in patterns. E5, the only elephant to exhibit no stereotypy throughout the entire study also showed the same pattern in exploration, as did E3 and E4, who were most commonly observed in stereotypic behavior in the early morning before the arrival of the keepers. This suggests that both stereotypy and exploration may serve as “filler” activities for the elephants as they wait for the next major event of the day (e.g., feeding time).

Limitations

In addition to the variables previously mentioned (e.g., social rank, social grouping, health), there are other factors that should be considered when interpreting the
results of this study. Due to small sample size, it was necessary to use non-parametric statistics to investigate the effects of the different management conditions. As a result of individual differences, there was not a single behavior that changed in the same direction across all elephants between phases. In every behavioral state some elephants increased the amount of time spent engaged in that behavior between phases while others decreased the behavior. As the Friedman analysis used in this study ranks each individual’s behavior in each condition (assigning the highest value a 1, the next highest a 2, and the lowest a 3) and subsequently averages the ranks within each condition, this variability between individuals likely made any differences between phases a wash. The small sample size also limits the ability to generalize the results of this study to other zoo elephants.

Additionally, age-effects may have contributed to the results of the study; all the elephants at SDZ were older than 30 years of age at the time of the study. Although little has been published directly on the influence of age on behavior in zoo elephants, a general pattern of differences between various age groups can be inferred from the results of other studies on zoo elephant behavior. For instance, Rees (2009) examined the relationship between feeding and stereotypy in a group of Asian elephants whose ages ranged from 1 year to 43 years. The juvenile elephants in this study had higher levels of activity throughout the 4-hour observation period, locomoting twice as much as the adults. The juveniles in this study also engaged in less stereotypic behavior. Posta et al. (2013) reported on the effect of season and housing condition on the diurnal behavior of a female African elephant and her 3-year-old calf. The calf spent more time interacting with enrichment items, lying down, and exploring the environment than the adult. In addition to these behavioral differences, older elephants are more likely to have age-
related health issues, such as arthritis (Lewis et al., 2010), that may limit mobility and therefore influence activity levels. With these age differences in behavior in mind, it is possible that the results of the study may have been different with a younger herd.

Implications of the Study

While there were few significant changes in behavior across subjects in response to the changes in management routine, the individual responses observed in this study may have important implications for the use of these management strategies at SDZ in the future. E1 exhibited a strong response to the change in rototilling frequency, substantially reducing his activity levels and spending a significant amount of time resting. Perhaps the best management strategy for this individual is to limit rototilling to periods when the substrate becomes extremely compacted.

Even though there was no significant increase in foraging-related behaviors when unpredictable foraging opportunities were provided, the general decrease in resting behavior observed in Phase 3 for a majority of the elephants suggests that this management technique may have been useful in increasing the elephants’ activity levels. However, due to the increased stereotypic behavior in some of the elephants during this phase, if this technique continues to be utilized in the future, keepers should consider making other foraging opportunities available during the hours when staff members are not present.

It would be erroneous to conclude that rototilling at a greater frequency did not provide any benefits to the elephants simply because there were no significant changes in the locomotor behavior, recumbent resting, or walking distances/rates of the elephants. It is possible that the softer substrate present in the weekly rototilling condition (Phases 2 and 3) required the elephants to work harder when moving from one location to another.
For humans, the mechanical work required when walking on soft substrates such as sand or snow is up to 2.5 times greater than that required on a compact surface (Lejeune, Willems, & Heglund, 1998), resulting in a higher heart rate and increased oxygen uptake (Zamparo, Perini, Orizio, Sacher, & Ferretti, 1992). Moreover, muscle and tendon efficiency is reduced on soft terrain (Lejeune et al., 1998), ultimately requiring the muscles to work harder during locomotion. While the mechanics of human movement differs from that of elephants, it is likely that elephant locomotion also incurs a greater energetic cost in softer substrates and may result in similar outcomes (e.g., increased cardiovascular or muscle/tendon activity). Therefore, although the elephants did not walk significantly farther when rototilling was increased, it is possible that they experienced enhanced exercise benefits from this management strategy that were not evident from the current analysis.

Another possible benefit the elephants may have gained from the presence of softer substrates is a reduction in foot pressure while standing or locomoting. Foot pressure is a critical factor in an elephant’s foot health and is of particular concern for elephants that are older, lethargic, or overweight (Roocroft, 2005). Recently, Panagiotopoulou, Pataky, Hill, & Hutchinson (2012) mapped the foot pressure of locomoting Asian elephants using a neuroimaging technique. The authors discovered that the highest foot pressure values were on the distal ends of the lateral toes and suggested there may be a link between the foot pathologies that are common among zoo elephants (e.g., nail cracks, osteomyelitis, osteoarthritis) and these peak pressure regions. Softer substrates may provide additional cushioning while an elephant stands or locomotes and, in turn, may offload some of the pressure on these high pressure points.
Future Directions

The current study provides a foundation for future research on the effects of rototilling and/or unpredictable feeding opportunities on elephant behavior. The following are some areas where zoo professionals might focus:

- How does weekly rototilling affect the overall foot health of elephants? Using photographic and/or ultrasonic scanning techniques (Abu-Seida, Mostafa, & Tolba, 2012; Badawy, 2011), future studies should examine whether there are substantial changes in foot pathologies (e.g., footpad wear, pododermatitis, osteomyelitis, etc.) under weekly versus monthly rototilling conditions.

- Does providing unpredictable foraging opportunities have a different effect on behavior when provided at different times of day? In the current study, the unpredictable foraging opportunities were only available during the daytime when keepers were present to raise/lower the hay bags. By automating the process with a computerized system, this enrichment could be offered at any time of day. Perhaps making this enrichment available in the morning before the keepers arrive would reduce the anticipatory stereotypy that seems to be prevalent at this time. Moreover, providing this type of enrichment after the evening feeding (but before the late night resting period) might result in higher activity levels and walking rates at this time.

- Does incorporating some level of predictability to the access of hay bags within the current feeding enrichment have an effect on the elephants’ activity levels and behavioral diversity as Watters et al. (2011) demonstrated with fennec foxes?
• How is exhibit use influenced by the use of unpredictable foraging enrichment? Do elephants utilize more or less of their exhibit space when this enrichment is provided? Do some individuals monopolize areas where this enrichment occurs?

Summary

The present study highlights the importance of evaluating the effectiveness of animal management routines at the individual level rather than solely assessing group-level changes. At the group level, the results of the current study indicated few changes in the behavior of the elephants in response to the changes in management routine. However, at the individual level, some interesting and important patterns emerged, suggesting that certain management techniques may not be suitable for all individuals.

Moreover, the results presented here emphasize the need for the behavioral effects of enrichment to be assessed beyond keeper working hours. Without the “after hours” observations conducted in this study, the increase in stereotypy during the evening and early morning in Phase 3 would not have been detected. As a result, the potentially negative outcomes of providing unpredictable foraging in the manner in which it was implemented for this study might never have been considered.
APPENDIX A

INSTITUTIONAL ANIMAL CARE AND USE COMMITTEE APPROVAL

THE UNIVERSITY OF SOUTHERN MISSISSIPPI

Institutional Animal Care and Use Committee

118 College Drive #5147
Hattiesburg, MS 39406-0001
Phone: 601.266.4063
Fax: 601.266.4377

INSTITUTIONAL ANIMAL CARE AND USE COMMITTEE NOTICE OF COMMITTEE ACTION

The proposal noted below was reviewed and approved by The University of Southern Mississippi Institutional Animal Care and Use Committee (IACUC) in accordance with regulations by the United States Department of Agriculture and the Public Health Service Office of Laboratory Animal Welfare. The project expiration date is noted below. If for some reason the project is not completed by the end of the three year approval period, your protocol must be reactivated (a new protocol must be submitted and approved) before further work involving the use of animals can be done.

Any significant changes (see attached) should be brought to the attention of the committee at the earliest possible time. If you should have any questions, please contact me.

PROTOCOL NUMBER: 12121301
PROJECT TITLE: Activity patterns and behavioral profiles of post-reproductive elephants
PROPOSED PROJECT DATES: December 2012 – September 2015
PROJECT TYPE: New
PRINCIPAL INVESTIGATOR(S): Stan Kuczaj
DEPARTMENT: Psychology
FUNDING AGENCY/SPONSOR: Departmental
IACUC COMMITTEE ACTION: Full Committee Approval
PROTOCOL EXPIRATION DATE: September 30, 2015

Jodie M. Jawor, Ph.D.
IACUC Chair

[Signature]

[Date]
## APPENDIX B

### BEHAVIORAL DATA COLLECTION SHEET

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<th>Behavior</th>
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## APPENDIX C

### ELEPHANT BEHAVIOR ETHOGRAM: BEHAVIORAL EVENTS

<table>
<thead>
<tr>
<th>Behavioral Event</th>
<th>Operational Definition</th>
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<tbody>
<tr>
<td><strong>General</strong></td>
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</tr>
<tr>
<td>Drink</td>
<td>Subject collects water in trunk and squirts into mouth.</td>
</tr>
<tr>
<td>Eliminate</td>
<td>Subject urinates and/or defecates (U = urinate; D = defecate).</td>
</tr>
<tr>
<td>Explore</td>
<td>Subject sniffs and/or manipulates environment (e.g., walls, rocks, or objects in enclosure other than enrichment items).</td>
</tr>
<tr>
<td>Feed</td>
<td>Subject collects solid food with trunk and places in the mouth while standing or walking (does not include food obtained from feeder ball).</td>
</tr>
<tr>
<td>Lie</td>
<td>Subject lies down on ground on side or prone.</td>
</tr>
<tr>
<td>Locomote</td>
<td>Subject steps forward or backward; must take 3 steps to be scored (does not include walking while feeding or stereotyped locomotion).</td>
</tr>
<tr>
<td>Stand</td>
<td>Subject remains motionless (does not include dusting or stereotyping).</td>
</tr>
<tr>
<td>Other</td>
<td>Subject engages in a general behavior not listed.</td>
</tr>
<tr>
<td><strong>Self-Maintenance</strong></td>
<td></td>
</tr>
<tr>
<td>Bathe</td>
<td>Subject submerges all or part of body in water and/or uses trunk to toss water onto body.</td>
</tr>
<tr>
<td>Dig</td>
<td>Subject manipulates or moves substrate with foot or trunk.</td>
</tr>
<tr>
<td>Dust</td>
<td>Subject uses trunk to toss dirt, sand, mud, dung, hay, or browse on self.</td>
</tr>
<tr>
<td>Itch</td>
<td>Subject uses trunk, foot, or object (e.g. stick) to scratch part of body.</td>
</tr>
<tr>
<td>Roll</td>
<td>Subject lies down and wriggles around in soil or mud (not as part of social play with another elephant).</td>
</tr>
<tr>
<td>Rub</td>
<td>Subject rubs head or body against a wall, fence, rock, “utilitre,” or object.</td>
</tr>
<tr>
<td>Wallow</td>
<td>Subject submerges all or part of body in mud.</td>
</tr>
<tr>
<td>Other</td>
<td>Subject engages in a self-maintenance behavior not listed.</td>
</tr>
<tr>
<td>Behavioral Event</td>
<td>Operational Definition</td>
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<tr>
<td>------------------</td>
<td>------------------------</td>
</tr>
<tr>
<td><strong>Social</strong></td>
<td></td>
</tr>
<tr>
<td>Approach</td>
<td>Subject moves toward a conspecific.</td>
</tr>
<tr>
<td>Aggress</td>
<td>Subject hits/pushes or kicks at another individual as the result of an antagonistic encounter (does not include social play).</td>
</tr>
<tr>
<td>Caress</td>
<td>Subject rubs trunk over head or body of conspecific.</td>
</tr>
<tr>
<td>Charge</td>
<td>Subject rushes toward conspecific, ears wide, trunk tucked.</td>
</tr>
<tr>
<td>Displace</td>
<td>Subject approaches and overtakes position of conspecific.</td>
</tr>
<tr>
<td>Pursue</td>
<td>Subject runs after conspecific.</td>
</tr>
<tr>
<td>Share food</td>
<td>Subject feeds from same feeder or enrichment device as a conspecific.</td>
</tr>
<tr>
<td>Share object</td>
<td>Subject simultaneously handles same object with one or more conspecifics.</td>
</tr>
<tr>
<td>Spar</td>
<td>Subject makes head to head contact with conspecific. Can involve pushing trunks, shoving, tusking, or wrestling.</td>
</tr>
<tr>
<td>Trunk tangle</td>
<td>Subject gently entwines trunk with conspecific’s trunk.</td>
</tr>
<tr>
<td>Other</td>
<td>Subject engages in social behavior not listed.</td>
</tr>
<tr>
<td><strong>Object</strong></td>
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<tr>
<td>Investigate enrichment</td>
<td>Subject smells or explores enrichment item (e.g. toys, logs, barrels, etc.) with trunk, but does not move it.</td>
</tr>
<tr>
<td>Manipulate enrichment</td>
<td>Subject moves, pushes, tosses, picks up enrichment item.</td>
</tr>
<tr>
<td>Feeder ball</td>
<td>Subject moves, pushes, tosses, picks up feeder ball. Also includes consumption of any food items retrieved from feeder ball.</td>
</tr>
<tr>
<td>Other</td>
<td>Subject engages in an object-directed behavior not listed.</td>
</tr>
<tr>
<td><strong>Stereotype</strong></td>
<td></td>
</tr>
<tr>
<td>Bob &amp; sway</td>
<td>Subject repeatedly moves body side to side while nodding head up and down at the same time.</td>
</tr>
<tr>
<td>Head bob</td>
<td>Subject nods head up and down repeatedly while standing still.</td>
</tr>
<tr>
<td>Pace</td>
<td>Subject repeatedly walks along the same path of travel. Scored only when the subject completes three full repetitions of the pattern and begins a fourth.</td>
</tr>
<tr>
<td>Sway</td>
<td>Subject repeatedly shifts weight from one foreleg to the other, moving body in side to side motion.</td>
</tr>
<tr>
<td>Other</td>
<td>Subject engages in a repetitive behavior not listed.</td>
</tr>
</tbody>
</table>
## ELEPHANT BEHAVIOR ETHOGRAM: BEHAVIORAL STATES

<table>
<thead>
<tr>
<th>Behavioral State</th>
<th>Operational definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>Feed/Drink</td>
<td>Subject is engaged in behaviors related to feeding/drinking.</td>
</tr>
<tr>
<td>Explore</td>
<td>Subject is engaged in exploratory behavior such as investigating enrichment items or environment.</td>
</tr>
<tr>
<td>Keeper interaction</td>
<td>Subject is interacting with elephant care staff member, such as during a husbandry or training session.</td>
</tr>
<tr>
<td>Locomote</td>
<td>Subject is engaged in behaviors such as walking, trotting, etc. Does not include stereotypic locomotion.</td>
</tr>
<tr>
<td>Manipulate</td>
<td>Subject is engaged in object-directed behaviors such as manipulating enrichment or feeder ball.</td>
</tr>
<tr>
<td>Rest</td>
<td>Subject is inactive, either standing or lying down.</td>
</tr>
<tr>
<td>Self-maintenance</td>
<td>Subject is engaged in behaviors related to bathing/wallowing, digging, dusting, itching or rubbing.</td>
</tr>
<tr>
<td>Social</td>
<td>Subject is engaged in behaviors involving a conspecific (e.g., caress, displace, pursue, spar, trunk tangle, etc.).</td>
</tr>
<tr>
<td>Stereotypic</td>
<td>Subject is engaged in stereotypic behavior such as pacing or swaying. Type of stereotypy will be noted (BS = bob &amp; sway; P = pacing; SW = swaying).</td>
</tr>
<tr>
<td>Out of view</td>
<td>Subject is not in view of the observer or behavior cannot be determined.</td>
</tr>
<tr>
<td>Other</td>
<td>Subject is engaged in a behavioral state not listed above.</td>
</tr>
</tbody>
</table>
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*Journal of Mammalogy, 89*, 467-476.


*Koedoe, 47*, 91-104.


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