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The effects of GPS collars on African elephant (*Loxodonta africana*) behavior at the San Diego Zoo Safari Park

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ABSTRACT

The use of tracking devices (e.g., VHF radio collars, GPS collars, ear transmitters) enables researchers to assess activity budgets, species-specific movement patterns, effects of environmental enrichment, and exercise levels in zoo animals. The fundamental assumption in these studies of tagged animals is that attachable tracking devices have negligible effects on the animals' behavior. The present study examined solitary and social behavior rates, as well as overall activity budgets, in eight African elephants living at the San Diego Zoo Safari Park, Escondido, CA, USA. Each elephant was trained over several months to wear leather collars affixed with GPS units encased in watertight plastic containers. Behavioral data collected while the GPS collars were worn (16 daylight hours, 16 night hours) were compared to behavioral data when the GPS collars were not worn (16 daylight hours, 16 night hours) throughout June and July 2010. No significant differences ($P < 0.05$) in behavior rates or average percent of observation time the subjects were recorded in particular states were found. During the morning hours, while the collars were both worn and not worn, feeding was the most common behavior state ($M = 44.7 \pm 3.8\%$, $M = 49.3 \pm 15.3\%$), followed by resting ($M = 35.5 \pm 10\%$, $M = 37.3 \pm 12\%$) and walking ($M = 10 \pm 3.1\%$, $M = 8.7 \pm 1.9\%$). During the evening hours, feeding remained the most common behavior state for both worn and not worn conditions ($M = 66.1 \pm 12.3\%$, $M = 63.3 \pm 13.7\%$), followed by resting ($M = 17.6 \pm 7.7\%$, $M = 19.4 \pm 9.5\%$), and sleeping ($M = 8.1 \pm 8.9\%$, $M = 7.8 \pm 8.1\%$). This distribution of daily behavior state is similar to previous activity budgets examined in other zoo elephant herds. These results suggest that, with adequate training, GPS collars may have minimal impact on the behavior of zoo elephants.

1. Introduction

African elephants have been in North American zoos for over 200 years (Schulte, 2000). The current AZA studbook for the African elephant, a computerized database of each individual animal under human care, states that there are approximately 171 females and 73 males being exhibited in 65 institutions across North America (Olson, 2011). While 36 of these animals were born on-site at zoological institutions, the vast majority of the adults were caught in the wild as juveniles during the ivory trade of the 1970s and 1980s (Olson and Wiese, 2000). The maintenance of elephants in zoos requires that careful consideration given to exhibit size, compatible social grouping, sheer physical management, and health care (Clubb and Mason, 2003; Mason and Veasey, 2010; Veasey, 2006). There is an increased interest in the activity budgets of zoo elephants as it relates to both physical well-being (i.e., obesity, degenerative joint disease, foot health: Gage, 2001; Roocroft, 2005)

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and psychological welfare (Morgan and Tromburg, 2007; Shepherdson, 1999; Soltis and Brown, 2010).

This concern for variation in the activity budgets of zoological elephants has lead researchers to use advanced Global Positioning System (GPS) technology in order to track individual position within an exhibit. For example, Leighty et al. (2009) found that seven adult female African elephants housed at Disney's Animal Kingdom travel on average 0.41 km/h during the daylight hours. Miller et al. (in press) report that six adult females, one adult male and one sub-adult male of San Diego Zoo Safari Park walk an average of 0.36 ± 0.03 km/h throughout an entire 24 h period, and Rothwell et al. (2011) found an average walking rate of 0.41 km/h in two adult females of the same herd while comparing GPS collar data to accelerometer anklet data. The subtle differences in daily distance traveled may be due to variation in exhibit design, individual differences in energy level, and the various effects of climate and social grouping.

Utilizing numerous methods including in-field tracking (Merz, 1986), VHF radio collars (Slotow and van Dyk, 2004; Whitehouse and Schoeman, 2003), and the enhanced technology of Global Positioning System (Galanti et al., 2006; Lindeque and Lindeque, 1991; Wittemyer et al., 2007), researchers have determined that wild African elephants vary their location based on the seasonal availability and distribution of resources (Guy, 1976; Viljoen, 1989). When environmental conditions are stable, the average level of movement in wild elephants is between 0.21 and 0.42 km/h (see Leighty et al., 2009 for review).

Another contributing factor to the differences in walking rate seen throughout zoological studies may be the unknown behavioral side-effects of attachable tracking devices (VHF radio collars, GPS collars, ear transmitters and accelerometers). The construction of durable and reliable tracking devices requires the use of heavy-duty materials. The underlying assumption in all animal activity budget studies is that tagging an animal will not bias natural behavior. Previous research on other mammals has both supported (white-tailed deer (*Odocoileus virginianus*): Moll et al., 2009) and refuted this assumption (mountain goats (*Oreamnos americanus*): Côté et al., 1998; moose (*Alces alces*): Swenson et al., 1999). Brooks et al. (2008) tested various weights and fittings of GPS collars on plains zebras (*Equus burchelli antiquorum*) and found that rate and distance traveled were significantly affected. The heavier collars (0.6% of body weight) reduced the zebras' travel rate by more than 50% when the animals were grazing. Conversely, Nussberger and Ingold (2006) did not observe behavior differences in female alpine chamois (*Rupicapra rupicapra*) in the Swiss Alps which wore radio-collars for over a year. The non-collared chamois showed no difference in inter-animal distances or behavior toward the collared chamois (Nussberger and Ingold, 2006). Moll et al. (2009) found that the weight of animal-borne video and environmental data collection systems (AVEDs) did not cause deleterious physiological effects in white-tailed deer. Stress-indicating fecal glucocorticoid levels in deer with video collar attachments were similar to the concentrations seen in non-collared deer (Moll et al., 2009).

Generally, the GPS transmitters are placed within a protective compartment (i.e., water-tight plastic box) which is subsequently attached to a flexible collar usually made from the strong filaments of a fire hose or leather. The recommended weight of these devices ranges from a ratio of 0.7–9% of total body mass (Berteaux et al., 1996; Brooks et al., 2008; Macdonald, 1978). GPS collars used in elephant studies generally range from 2 to 3 m in length, 7–10 cm in width, and the entire collar with transmitting unit attached weighs on average 2–5 kg (Followit Wildlife, 2010; Leighty et al., 2009; Rothwell et al., 2011; Telonics, 2010).

Tracking an animal's natural movement pattern provides vital information regarding seasonal and diurnal activity levels, species-specific movement patterns, and habitat use. This knowledge is greatly beneficial in assessing the effectiveness of environmental enrichment, exhibit use patterns, and evaluating adequate exercise levels in zoological animals. Given that the affects of GPS collars on movement patterns is unknown, the present study examined the solitary and social behavior effects of GPS collars on eight zoological elephants.

2. Methods

2.1. Study site and subjects

At the time of this study, the San Diego Zoo Safari Park in Escondido, CA, USA housed a herd consisting of one bull, six cows, one male sub-adult, one male juvenile, two female juveniles, one male calf, and three newborn male calves. The 1.3 ha exhibit contains various topography consisting of dirt, rock, mud, grass, and includes accessories of trees, shade structures, a bathing pool, and two indoor barn facilities (Rothwell et al., 2011). Behavior data were collected on all 15 elephants of this herd during the summer of 2010 for 12 weeks from late May to early August as part of a separate long-term behavior research project. Observations took place at the perimeter section of the elephant exhibit which is closed off to the public. This enabled the observer to follow and track each elephant when they traveled out of public view.

Prior to this study, the bull, six cows and the sub-adult male were conditioned to wear GPS collars in order to examine averages and trends in walking rates (for details see Miller et al., in press). This training process involved a structured desensitization of the collars, using positive reinforcement, over several months. The elephants were first trained to stand parallel to the protective barriers to allow the keepers to have safer access to the animals. The keepers would then reach through the bars to place the leather collars over the animals' necks and fasten the belting below the neck. The GPS tracking units (Qstarz BT-Q1000X [Taipei, Taiwan]) were encased in waterproof plastic containers (Pelican™ Micro Case #1020 [San Antonio, TX, USA]) and affixed to leather beltings (TechNicol LTD, Cambridge, UK). The GPS units were placed on the top of the neck between the ears of each elephant and weighed approximately 1.87 kg (see Rothwell et al., 2011 for details). At the time of data collection, the animals' weights ranged from 2268 to 4536 kg, which would place the GPS units at nearly 0.04–0.08% of total body weight. The length of time