Research Paper

Anthropogenic influences on the time budgets of urban vervet monkeys

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ABSTRACT

Continuing urban developments are ecologically changing many landscapes. A greater understanding of how wildlife adapt behaviorally to these changes is necessary to inform management decisions. Time is a valuable resource to wildlife and a reflection of ecological pressures on the behavioral repertoire of an animal. Data on urban vervet monkey, *Chlorocebus pygerythrus*, time budgets are generally limited and dated. We aimed to investigate the effect of anthropogenic influences, both human food consumption (positive) and human-monkey conflict (negative) on the time budgets of vervet monkeys in an urban landscape. We collected 20 min. focal animal observations and used generalized linear mixed models to assess the variation in time budget between five urban vervet monkey groups differing in anthropogenic contact over one year. We recorded anthropogenic interactions as positive and/or negative. Our results showed seasonal influences across all behaviors. Furthermore, anthropogenic disturbance influenced all aspects of time budget to some degree. We found a positive interaction effect between positive and negative human incidents on foraging, and a negative interaction effect on movement and social behavior. Overall, vervet monkeys exhibited behavioral flexibility in the urban landscape. We suggest a complex association of costs and benefits to urban living.

1. Introduction

Increased human populations and urban developments are transforming many wildlife habitats (McKinney, 2006). Human expansion has led to a growing interest in understanding behavioral responses of species to urbanization for urban management plans (e.g. Jokimäki et al., 2011). Wildlife has been shown to adapt to these changes in many ways including modifying foraging behavior, predator behaviors and activity patterns (Jokimäki et al., 2011). Information on how wildlife adapt behaviorally to these changes can be key for management decisions (Ditchkoff, Saalfeld, & Gibson, 2006; Marzluff, Bowman, & Donnelly, 2001). Time budgets have been applied to a variety of species to study the effect of varying levels of anthropogenic disturbance (e.g. Jokimäki et al., 2011). However, studies including high-density towns and cities are scarce, furthermore, positive associations of urban living for wildlife behavior are rarely considered, despite being necessary, to develop suitable management plans (McLennan, Spagnoletti, & Hockings, 2017).

Understanding the relationship between an animal and its environment can provide essential information for conservation management and urban planning (Patterson, Kalle, & Downs, 2018). Time budgets provide a useful method to test ecological hypotheses (Isbell &

Young, 1993) as they allow the representation of time allocation where trade-offs in behaviors are illustrative of the resources and time available (Dunbar et al., 2009). Time budget analyses have been employed across urban wildlife to demonstrate the effects of urbanization and landscape changes (burrowing owls, *Athene cunicularia hypugaea*: Chipman et al., 2008; gray squirrels, *Sciurus carolinensis:* Parker, Gonzales, & Nilon, 2014; bottlenose dolphins, *Tursiops aduncus*: Steiner, 2012).

Rapid human population growth and land-use changes have transformed many primate habitats (Estrada, Raboy, & Oliveira, 2012; Mckinney, 2015) and have resulted in a directional shift towards ethnoprimatology (Fuentes & Hockings, 2010; Hockings et al., 2015; McLennan et al., 2017; Strier, 2017). Although time budgets have been applied to assess primate behavioral flexibility to landscape change, the applications of these findings are largely limited to macaques (*Macaca* sp.) and baboons (*Papio* sp.) (McLennan et al., 2017). Anthropogenic assets such as high value food have been shown to decrease foraging time (Hoffman & O'Riain, 2011; Jaman & Huffman, 2013; Saj, Sicotte, & Paterson, 1999; Sha & Hanya, 2013) which often occurs in parallel with a decrease in movement (Jaman & Huffman, 2013; Wong & Candolin, 2015) and associated with an increase in social interactions (Jaman & Huffman, 2013; Saj et al., 1999; Scheun, Bennett, Ganswindt,

& Nowack, 2015).

Seasonality is a strong predictor of time budgets in wild primates (Fan, Ni, Sun, Huang, & Jiang, 2008; Hendershott, Behie, & Rawson, 2016; Zhou et al., 2007), however, primates living in urban landscapes are often buffered against the effects of seasonality. Reports of seasonality on anthropogenically influenced monkeys are mixed. Some studies show no influence of seasonality, expressing this as a result of a continuous supply of high value resources available (Altmann & Muruth, 1988; Eley, 1989). Recent studies of more anthropogenically disturbed primates have shown that seasonality is influential on time allocation and suggest this to be an adaptive exploitive behavior (macaques; Jaman & Huffman, 2013, and baboons; Van Doorn, O'Riain, & Swedell, 2010).

Prior research has assessed aspects of the landscape that influence the success and survival of vervet monkeys, *Chlorocebus pygerythrus*, in a modified anthropogenic environment (Chapman et al., 2016; Patterson, Kalle, & Downs, 2016). Although studies have considered time budgets of anthropogenically disturbed primates, no study has has yet assessed the flexibility in time budgets of an adapted generalist primate living in such a highly human populated urban setting. Furthermore, past research has only considered the consequences of either human/wildlife conflict (negative aspects) or access to high value resources (positive aspects) (McLennan et al., 2017). Studies examining the interaction between these negative and positive aspects are needed. As vervet monkeys continue to succeed in the ecologically developing urban landscape, the human wildlife conflict between vervet monkeys and local residents continues to grow with negative consequences for vervet monkeys (Wimberger & Downs, 2010; Wimberger, Downs, & Perrin, 2010). Vervet monkey population expansion in urban lansdscapes raises concerns both for vervet monkey wellbeing (Wimberger & Downs, 2010; Wimberger, Downs, et al., 2010) and ecological biodiversity conservation (Díaz, Fargione, Iii, & Tilman, 2006)

We aimed to investigate the effect of anthropogenic influences, both human food consumption (positive) and human-monkey conflict (negative) on the time budgets of vervet monkeys in an urban landscape. In order to do this, our main prediction focussed on ecological and landscape constraints. We predicted that anthropogenic disturbance would affect urban vervet monkeys' time budgets (Jaman & Huffman, 2013; Saj et al., 1999; Scheun et al., 2015). We predicted that positive anthropogenic aspects would decrease movement and foraging and increase social behavior as a trade off in time availability.

2. Methods

We conducted our study at Simbithi eco-estate, a private gated housing estate in Durban north coast, KwaZulu-Natal, South Africa (29.5140° S, 31.2197° E). The estate was previously two sugar cane farms that were developed 20 years ago to form a 430 ha estate (Simbithi eco-estate, 2017, pers. comm.). The estate was comprised of a variety accommodation options including apartment blocks, retirement complexes and general housing within a green mosaic. The estate had other anthropogenic leisure developments including restaurants, shops, fitness facilities, a golf course and a hotel. The estate encouraged wildlife research to help biodiversity management plans. Residents had mixed responses to vervet monkey presence ranging from actively encouraging vervet proximity to humans (intentional feeding by humans) to actively deterring vervet monkeys from human property (human aggression).

Vervet monkeys are commonly found in urban settings of KwaZulu-Natal (Thatcher, Downs, & Koyama, 2018) and therefore provided a candidate model to assess behavioral flexibility under anthropogenic changes (Chapman et al., 2016; Saj et al., 1999). The estate contained seven groups of vervet monkeys (Simbithi eco-estate, 2017, pers. comm.), although this study only considered the five groups that regularly stayed within the borders of the estate. Group size varied from 14 to 42 individuals (Ballito (14): 3 males, 6 females, 5 juveniles;

Farmyard (23): 4 males, 10 females, 9 juveniles; Savannah (25): 4 males, 10 female, 11 juveniles; Goodies (29): 5 males, 10 females, 14 juveniles; Herron (42): 5 males, 14 females, 23 juveniles). This was the first study on these groups so their history was unknown. Most monkeys were well habituated to humans due to the regular proximity to human residence. Two months were spent prior to commencing behavioral observations identifying monkeys. All adult vervet monkeys were identifiable via distinguishable markings, therefore, all 71 adult vervet monkeys were observed for this study.

We collected data from March 2016 to February 2017. We conducted observations from dawn until dusk (up to 8 h in winter and 16 h in summer) for a minimum of three weeks per month. Where possible we conducted a minimum of one observation per monkey per month, spread throughout the day (mean ± SD number of observations per group in the morning = 217 ± 33, midday = 251 ± 19 and afternoon = 286 ± 40). In total 3774 focal animal observations were conducted across all groups, averaging 650 ± 173 min per monkey.

We used focal animal sampling techniques (Altmann, 1974) to observe each individual for 20 min, sampling all group members before repeating observations in each month. We chose four key mutually exclusive categories to represent time budget defined as foraging: a monkey actively searching for food items before feeding and directly consuming food items found (food items include, plants, aesthetic garden plants and human derived food) (Ménard et al., 2013; Saj et al., 1999); movement: included all types of locomotion not associated with any other activity, for example walking, running, climbing, and jumping (Ménard et al., 2013; Saj et al., 1999); resting: monkey in an inactive posture that excludes interacting with others, in a motionless position for longer than five seconds (Saj et al., 1999); social: monkey interacting with at least one other monkey including both affiliative and agonistic behaviors (Ménard et al., 2013; Saj et al., 1999).

During dawn until dusk follows of each group, we used all occurrence sampling to record all interactions between humans and vervet monkeys. We identified a human related incident as any occasion when at least one vervet monkey interacted with humans or their related possessions (car, house, bin etc.). For positive human incidents we included any form of human-food consumption (e.g. bread, fruit, pizza). An incident was classed as terminated once all human food was consumed, if the monkeys then obtained human food after 20 min we classed this as a new event. Negative human incidents were classed as any form of human-monkey aggression directed towards vervet monkeys (chase, rocks thrown etc.). Such interactions represent a cost to the vervet monkey due to the energy expended (running away) and risk of injury. We classed an incident as terminated once all parties had retreated and we recorded new events if there had been no incident in the prior 20 min. Positive and negative human incidents were not mutually exclusive, a human event could be coded twice as both positive and negative (e.g. monkey takes food from human house [positive] and is chased away [negative]). To support our monthly human values we also created an estimated monthly value of natural food availability. Following practiced phenology protocol we conducted five randomly placed walking transects within each group's home range noting all specimens ≥10 cm diameter at breast height (Marshall & Wich, 2013). We retrospectively identified windows of fruit and flower availability using horticultural records for the region as in some previous studies (Blake, 1990; Wirminghaus, Downs, Symes, & Perrin, 2001). We split our data seasonally based on the four calendar seasons (summer: November-March, spring: September-October, autumn: April-June, winter: July-September) (SANBI, 2018).

2.1. Statistical analyses

For human values, we calculated a monthly rate (per hour) per group based on how many incidents were observed according to hours of field observation each month. For behavioral observations we converted the total duration(s) of behavior to percentage of time spent