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Capture, immobilization, and Global Positioning System collaring of olive baboons (*Papio anubis*) and vervets (*Chlorocebus pygerythrus*): Lessons learned and suggested best practices

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Abstract
As the value of Global Positioning System (GPS) technology in addressing primatological questions becomes more obvious, more studies will include capturing and collaring primates, with concomitant increased risk of adverse consequences to primate subjects. Here we detail our experiences in capturing, immobilizing, and placing GPS collars on six olive baboons (*Papio anubis*) in four groups and 12 vervet monkeys (*Chlorocebus pygerythrus*) in five groups in Kenya. We captured baboons with cage traps and vervets with box traps, immobilized them, and attached GPS collars that were to be worn for 1 year. Adverse consequences from the trapping effort included incidental death of two nonsubjects (an adult female and her dependent infant), temporary rectal prolapse in one baboon, superficial wounds on the crown of the head in two vervets, and failure to recapture/remove collars from two baboons and two vervets. Obvious negative effects from wearing collars were limited to abrasions around the neck of one vervet. A possible, and if so, serious, adverse effect was greater mortality for collared adult female vervets compared with known uncollared adult female vervets, largely due to leopard (*Panthera pardus*) predation. Collared animals could be more vulnerable to predation because trapping favors bolder individuals, who may also be more vulnerable to predation, or because collars could slow them down or make them more noticeable to predators. Along with recommendations made by others, we suggest that future studies diversify trapping bait to minimize the risk of rectal prolapse, avoid capturing the first individuals to enter traps, test the movement speeds of collared versus noncollared animals, include a release system on the collars to avoid retrapping failure, and publish both positive and negative effects of capturing, immobilizing, and collaring.

KEYWORDS
adverse effects of collars, biotelemetry, Global Positioning Systems, positive outcomes, primates

1 | INTRODUCTION

Rapid advances in biotelemetry using Global Positioning System (GPS) technology, including a reduction in the weight of wearable units with transmitters, are now making it possible to investigate difficult spatio–temporal issues in animal behavior and ecology, such as migration patterns (e.g., McKinnon & Love, 2018), long-distance dispersal (e.g., Earl et al., 2015), diel activity and habitat selection (e.g., Van Cleave et al., 2018), and collective decision-making in group travel (e.g., Strandburg-Peshkin, Farine, Couzin, & Crofoot, 2015). GPS collars have been deployed on many animal species (Tucker et al., 2018) but they are less commonly used with primates, in part because the typical observational approach of following habituated primates on foot allows animal locations to be estimated in other ways, including with handheld GPS units (e.g., Eckhardt, Polansky, & Boesch, 2015; Noser & Byrne, 2007; Santhosh, Kumara, Velankar, & Sinha, 2015; Schreier & Grove, 2010). Although locational data obtained with handheld GPS units are likely to be comparable with those obtained by GPS collars worn by animals if the observer follows the animal's path or corrects for the spatial displacement between the handheld unit and the animal (e.g., Noser & Byrne, 2007), GPS collars do not require observers to be present with the study animals and thus are useful for investigating questions that have been largely out of reach to date because of the limitations of observers, such as nocturnal movements of diurnal primates (Isbell, Bidner, Crofoot, Matsumoto-Oda, & Farine, 2017), complex spatial relationships within and among groups (Farine et al., 2016; Farine, Strandburg-Peshkin, Couzin, Berger-Wolf, & Crofoot, 2017; Markham, Alberts, & Altmann, 2016; Markham, Guttal, Alberts, & Altmann, 2013), and spatio–temporal interactions between primates and their predators (Bidner, Matsumoto-Oda, & Isbell, 2018; Isbell & Bidner, 2016; Isbell, Bidner, Van Cleave, Matsumoto-Oda, & Crofoot, 2018). Given the value of data obtained from GPS collars, more trapping and GPS collaring of primates will likely occur in the future.

The few primate-focused studies in which GPS collars have been deployed thus far have largely presented various kinds of data on collar performance (e.g., Markham & Altmann, 2008; Pebsworth, Morgon, & Huffman, 2012; Sprague, Kahaya, & Hargihara, 2004). Although documenting GPS-collar performance is important at this relatively early stage to test their value in primate-typical habitats, improve the effectiveness of collars, and determine the best type of collar for a given study, we concur with many that it is also important to discuss the extent to which the process of GPS-collar placement affects the animals themselves, with the goal of minimizing negative effects on individuals in the future (Ancrenaz, Setchell, & Curtis, 2003; Brett, Turner, Jolly, & Cauble, 1982; Honess & MacDonald 2003; Jolly, Phillips-Conroy, & Müller, 2003; Juarez, Rotundo, Berg, & Fernández-Duque, 2011; Jung & O'Donovan, 2005; Jung, Thompson, Hickey, & Titman, 2002; Trayford & Farmer, 2012). However, data are rarely presented on the collaring procedure itself or on the health, survival, or reproduction of collared individuals (Fehlmann et al., 2017; Markham & Altmann, 2008; Markham et al., 2013; Pebsworth et al., 2012; Pyritz, Kappeler, & Fichtel, 2011; Ren, Li, Long, Grüter, & Wei, 2008; Sprague et al., 2004). In the one exception, we found, it was reported that of 16 yellow baboons (*Papio cynocephalus*) wearing GPS collars for approximately 10 months, one suffered from a heavy tick infestation with infection and abrasions around the neck and one died 52 days after collaring (Markham et al., 2013). The current lack of reporting appears to be in contrast to earlier studies that reviewed the effects of often much lighter standard radio transmitter collars (e.g., Gursky, 1998; Juarez et al., 2011; Karesh et al., 1998).

Here we describe our experiences in trapping, immobilizing, attaching GPS collars, and recapturing to remove collars in olive baboons (*Papio anubis*) and vervet monkeys (*Chlorocebus pygerythrus*) in Kenya as part of a 14-month investigation of predator–prey interactions that required us to monitor most groups remotely. Although before our study we had sought advice from primatologists and veterinarians with experience capturing and collaring primates, by the end of our study it was clear that they had not experienced some of our problems. This suggests that there is still more to learn about the process of capturing and collaring primates and the effects of wearing collars on primate health and survival. We thus (a) highlight the problems we encountered and the decisions we made in uncertain situations, (b) offer possible explanations for negative outcomes, and (c) develop recommendations to better prepare those planning to deploy GPS collars on primates in the future.

2 | METHODS

2.1 | Study site and animals

We conducted the study at the Mpala Research Centre in Laikipia County, Kenya (0.29°N, 33.90°E), between December 2013 and January 2015, with additional retrapping attempts in January 2016. Mpala is a semiarid (443.2 mm rainfall in 2014) woodland-savannah cattle ranch and wildlife conservancy with a nearly intact community of wild mammals (Augustine & McNaughton, 2004; O'Brien & Kinnaird, 2011).

We (Kenya Wildlife Service veterinarians and field primatologists experienced with baboons and vervets) trapped, immobilized, and collared six adult female olive baboons as representatives of four different groups and 12 adult female vervets as representatives of five different groups. We targeted adult females because unlike juveniles, they have stopped growing, and unlike adult males, they are philopatric. Moreover, since groups are cohesive, the locations of the females would be representative of the locations of their groups, a necessary requirement of our study on predator–prey interactions. We attempted to collar a maximum of two adult females per group to provide a back-up if one of the females died during the year, with the expectation that the chance of both females dying from the same group was low. One baboon group and two vervet groups were already habituated to human observers and individuals in those groups were known and censused almost daily. We minimized contact with the other groups to avoid interfering with predator–-prey interactions, the main focus of the study, and so could not identify most individuals in the other groups. For additional details see Isbell et al. (2018).

2.2 | Trapping

We placed up to four traps near primate sleeping sites and spent 3 weeks spreading dried maize in and around inactive traps to habituate the primates to the traps before trapping. Following Jolly et al. (2003), we used 1 m^3 square wire cage traps for baboons. We used dropbox traps modified from Grobler and Turner (2010) for vervets (Figure 1). Throughout the trap habituation stage, the cage trap doors were tied open with rope and the box traps were propped up with metal poles screwed into them to prevent accidental trapping. Animals were free to go in and out of the traps during this stage.

In both species, adult males were the first to enter the traps. After adult female baboons began to feed in the cage traps, we prepared to trap at their sleeping sites by adding bait, untying the trap doors, and tying a long rope to each of the doors just before dawn. We held the ropes taut from a vehicle positioned at least 20 m away to keep the trap doors open until adult females entered. When a female was fully inside a trap, we released the rope, causing the trap door to fall. Female baboons were captured over the course of 4 days during which a separate study group was targeted for trapping each day.

After adult female vervets began to feed beneath the box traps, we prepared to trap at their sleeping sites before dawn by adding bait, unscrewing the plates securing the metal poles to the box traps, tying a long rope to each pole, and then holding the ropes slack while in a vehicle positioned at least 20 m away. When an adult female fed under the trap, we pulled the rope, which released the metal pole and caused the box trap to fall. We captured nine vervets over 7 days, 3 more over 4 days 2 months later, and all but one in the morning. That vervet lived in a group whose home range encompassed the research station, where the group often slept on roofs or trees adjacent to station buildings.

2.3 | Immobilization

For collar placement, we (veterinarians GO or MM) immobilized both species with 10 mg/kg ketamine hydrochloride (Agrar Holland BV, Soest, The Netherlands). The injections were administered to baboons with a blowpipe between 06:50 and 08:33 hr and to vervets with a syringe through the wire mesh of the box trap between 06:51 and 09:37 hr and at 15:53 hr. Drug dosages were estimated based on visually assessed body mass of trapped individuals. Two baboons had to be given additional injections of ketamine to fully sedate them. When the animals were immobilized, we removed them from the traps, cleared their buccal pouches of maize to avoid asphyxiation, assessed their respiration, and took body measurements. We report neck circumferences here because they are rarely reported but essential to know for collaring (baboons: mean = 34.2 cm ± 3.54 standard deviation [*SD*], range: 29–38 cm, $n = 6$; vervets: mean = 16.6 cm ± 2.0 *SD*, range: 12–19 cm, $n = 12$). Mean body mass of adult female baboons was 12.0 kg ± 2.39 *SD* (range: 9.5–15.5 kg, $n = 5$) and of adult female vervets, 3.0 kg ± 0.5 *SD* (range: 2.5–3.9 kg; $n = 11$). Infant vervets remained on their mothers during the collaring procedure, and we weighed those without clinging infants using a hanging scale (no lactating baboons were captured). For collar removal, we (MM or GO) administered ketamine to all individuals, and for one vervet and two baboons MM also administered medetomidine hydrochloride (0.04 mg/kg; Pfizer Laboratories (Pty) Ltd., Sandton, South Africa) and the reversal agent atipamezole hydrochloride (0.1 mg/kg; Kyron Laboratories (Pty) Ltd., Johannesburg, South Africa). Ketamine and medetomidine both have a wide safety margin, and they can be used separately or together to achieve deep or light anesthesia depending on protocol and animal status (Ancrenaz et al., 2003; Murphy, 2008). Atipamezole reverses the effects of medetomidine quickly (Ancrenaz et al., 2003).

2.4 | Collar placement

The baboon collars were made of double-layered canvas material treated to impart stiffness and water resistance and were adjustable

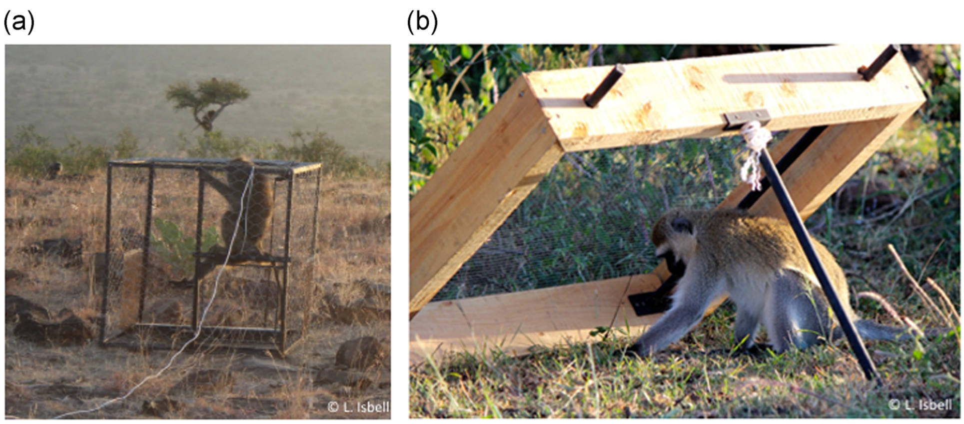

FIGURE 1 (a) An example of the cage traps used to capture olive baboons (*Papio anubis*) for collaring with Global Positioning System units. An adult female baboon has been caught and is inside the cage. (b) An example of the box traps used to capture vervets (*Chlorocebus pygerythrus*), with an adult male inside it during the pre-baiting period when the prop was screwed securely to the box to prevent accidental deployment

in circumference. A representative collar weighed 450 g, and included a D-sized battery, a GPS unit, and an accelerometer data logger (Savannah Tracking, Inc., Nairobi, Kenya). Their estimated lifespan was 12 months at a fix interval of 15 min throughout the 24-hr diel period. All but three were functional for the entire study. One baboon collar failed after 10 months, one was retrieved when the baboon wearing it was killed by a leopard, and the status of one is unknown as neither the collar nor its signal was located after the individual wearing it disappeared and was presumed to have died.

The vervet collars were made of nylon webbing with a mass of 140 g, including a C-sized battery, a GPS unit, and an accelerometer data logger (Savannah Tracking, Inc.). They were estimated to last 7 months at the same fix interval as the baboon collars but those worn by females that remained alive for the duration of the study were functional for 12 months, until the study ended. We secured the collars on the animals and considered them properly fitted if we could slip one finger between the collar and the neck. We did not attempt to pull the collar over the animal's head because the neck was always much smaller than the cranium. All collars but one were ≤5% of the animals' body mass, and that one was 5.6%, still well within the American Society of Mammalogists' guidelines of a maximum of 5–10% of body mass (Sikes & The Animal Care and Use Committee of the American Society of Mammalogists, 2016; Figure 2).

After collar placement, we put the primates in the shade and into either cage traps or two stacked box traps (with nonmesh ends fitted together) to allow the recovering individual room to sit and stand (vervets only). We recorded when recovering primates first raised their heads after ketamine injection (baboons: mean = 70 min ± 24 min *SD*, range: 36–106 min, $n = 6$; vervets: mean = 35 min ± 8 min *SD*, range: 22–47 min, $n = 12$), first sat up (baboons: mean = 86 min ± 29 min *SD*, range: 37–118 min, $n = 6$; vervets: mean = 50 min ± 13 min *SD*, range: 30–67 min, $n = 10$), and were released (baboons: mean = 159 min ± 41 min *SD*, range: 109–200 min, $n = 6$; vervets: mean = 114 min ± 21 min *SD*, range: 88–150 min, $n = 10$). The two baboons that were given additional injections of ketamine had the longest recovery times. We released all when they were fully able to walk, and for groups with two collared females, we released the two females together. All individuals immediately rejoined their groups except the first two collared baboons, whose group had moved away by the time they were released. Those two collared baboons remained together after their release and by the following day were back again with their group at their sleeping site.

2.5 | Recapture and collar removal

At the end of the study, we attempted to recapture the collared primates that were still alive to remove their collars. After 3 weeks of baiting with maize, we were able to recapture the two collared baboons that were in the habituated group. Veterinarian MM free-darted one because she avoided re-entering a cage trap. He darted her after following her on foot for 3 hours, after which she ran off and disappeared into thick vegetation. When we found her an hour later, she was given 5% dextrose infused intravenous fluid for peri-anesthetic management before removing her collar. We were unable to recapture the other two baboons in two other groups because they were not sufficiently habituated to free-dart and they frequently slept on another property where no cage traps had been set up.

We were able to recapture and remove the collars from four of the seven remaining collared vervets after 3–4 weeks of baiting with dried maize, or bananas if the maize was not a sufficient lure. One year later, we returned again to remove collars from the other three vervets. After baiting the traps with maize each morning for 3 weeks, we were able to remove the collar from only one female because the other two collared vervets still would not enter the traps. As of August 2018, 4.6 years after they were captured and collared, both females were still alive and both had reproduced since the last trapping effort in 2016.

The procedures in this study were reviewed and approved by the Institutional Animal Care and Use Committee at the University of

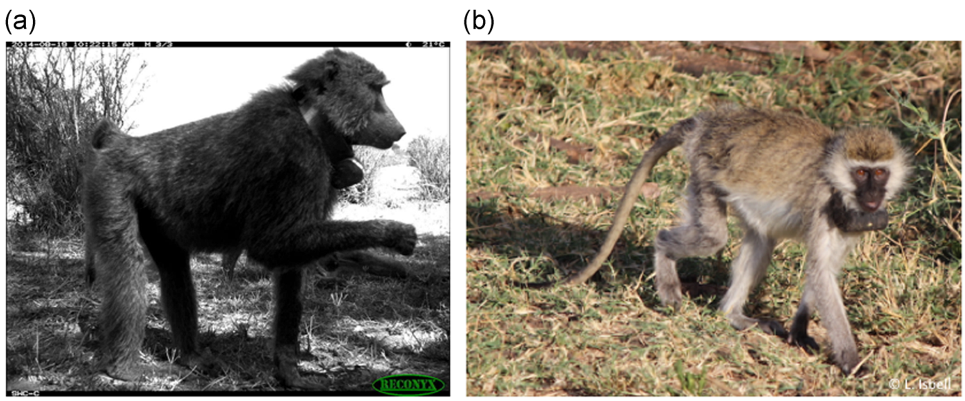

FIGURE 2 (a) Olive baboon wearing a Global Positioning System (GPS) collar. Adverse effects of the collaring procedures or the collars after 1 year of the deployment included a transient prolapsed rectum during trapping and permanent collar placement on two females who could not be retrapped. (b) Vervet wearing a GPS collar. Adverse effects of the collaring procedures or the collars after 1 year of the deployment included abrasions around the neck of one individual, potentially greater mortality from leopard predation, and permanent collar placement on two females who could not be retrapped

California, Davis (IACUC protocol #17477) and by the Kenya Wildlife Service. These procedures adhered to the American Society of Primatologists (ASP) Principles for the Ethical Treatment of Non-Human Primates.

3 | RESULTS

3.1 | Injuries

One of the first baboons we trapped developed a prolapsed rectum, which we believe resulted from a combination of heavy consumption of maize and distress as the baboon evaded us in the cage trap during our initial attempts to sedate her with a syringe (Taniguchi, Isbell, Bidner, & Matsumoto-Oda, 2019). When we switched to a blowpipe, she was immobilized quickly, and we were then able to reposition her rectum. We noted a small cut on the hand of the other female baboon trapped in that first group, possibly caused by a part of the metal cage. No other injuries were detected in baboons captured and collared. We found no abrasions around their necks at collar removal.

Two vervets were superficially wounded on the crowns of their heads as they scraped against the mesh wire of the box traps while trapped. We found abrasions around the neck of one vervet when we removed her collar, and we treated the abrasion with an oxytetracycline spray. No other injuries were detected.

3.2 | Mortality

Two of the six collared baboons, both from the same unhabituated group, died during the study. One was killed by a collared leopard (Isbell et al., 2018) 144 days after her capture (and transient prolapsed rectum), and we were able to retrieve her collar. Her separation from the other collared female for a week before her death and the location of her last sleeping site on a small boulder never used as a sleeping site before suggest she was incapacitated to some degree before she was killed (Bidner et al., 2018; Isbell et al., 2018). We were unable to locate the other baboon or the signal from her collar beyond 165 days after she was captured. We do not know if they had infants at the time of death because our focus on predator–prey interactions required minimizing our proximity to most primate groups. A comparison of mortality rates between collared and uncollared adult females in the one baboon group whose members were known and regularly censused revealed no statistical difference in mortality between them; both collared adult females survived the year whereas two of 16 uncollared adult females disappeared and were presumed dead (Fisher's exact test, $p = 0.78$, two-tailed).

In the first week of the trap habituation phase of the study, an adult female vervet from an unknown group was found dead with her young infant still clinging to her in an open cage trap baited to attract baboons. In addition to a wound on the crown of her head, she had multiple puncture wounds near her right jaw and below her left ear, the sizes of which suggested recent aggression from one or more conspecifics (see also Brett et al., 1982). Her infant remained with her but had died by the following day. We saw no wounds on it.

Five of the 12 collared vervets died during the study, and four collars were retrieved. Two died from unknown causes on Day 39 and between Days 76 and 87 after collar deployment. Accelerometer and GPS data revealed that the first female to die did not move for several hours before arriving at her final location during the night, suggesting that a scavenger found her dead and carried her body to this location (Isbell et al., 2018). Three of the collared vervets were suspected or confirmed to have died from leopard predation (Isbell et al., 2018) 46, 178, and 330 days after collar deployment. The mortality rate of collared vervets was significantly higher than that of their uncollared counterparts in the two groups whose members were known and regularly censused; four of six collared females died whereas all nine uncollared females survived (Fisher's exact test, $p = 0.01$, two-tailed).

The collars did not appear to reduce the survival or reproductive success of lactating females. Of the four mothers that were lactating at the time of collaring, only one died during the year-long study, whereas four of the eight nonlactating collared females died (Fisher's exact test, $p = 0.58$, two-tailed), and in the two groups with known individuals, the infants of two collared mothers survived the year whereas the infants of the other two collared mothers, as well as those of all three noncollared mothers, died (Fisher's exact test, $p = 0.43$, two-tailed). The mortality rate of collared vervets did not differ significantly from that of collared baboons (Fisher's exact test, $p = 1.0$, two-tailed).

4 | DISCUSSION

GPS collars have an advantage over VHF collars in that more precise and accurate data can be collected more often per unit time, data can still be recorded when the animals move in habitats difficult for researchers, and, depending on the collar specifications, data may also be obtained remotely at any time by the researcher (Hebblewhite & Haydon, 2010). These differences increase accuracy or detail in studies of ranging behavior, habitat selection, and movement ecology (Henzi, Brown, Barrett, & Marais, 2011; Klegarth et al., 2017; Latham et al., 2015; Ren et al., 2008; Van Cleave et al., 2018), and open up new lines of inquiry that are not easily addressed otherwise, such as spatio–temporal predator–prey interactions (Bidner et al., 2018; Isbell & Bidner, 2016; Isbell et al., 2018), nocturnal movements of diurnal animals (Isbell et al., 2017; Sprague et al., 2004), and spatial relationships within and among groups (Farine et al., 2016, 2017; Markham et al., 2013). Accelerometer data loggers can be added with little battery drain to GPS collars, further expanding possible topics to investigate, including the energetics of movement (Hernández-Pliego, Rodríguez, Dell'Omo, & Bustamente, 2017; Wilmers, Isbell, Suraci, & Williams, 2017) and nocturnal activities in diurnal animals (Isbell et al., 2017). With such promise, we expect greater use of GPS collars in the future, but because there are also potential costs to the study subjects, it is important for researchers to share their experiences to improve the welfare of captured animals (e.g., Jung & O'Donovan, 2005).

4.1 | Unexpected adverse outcomes or situations related to trapping

We encountered adverse outcomes from trapping, including a transient prolapsed rectum in a baboon and superficial wounds on two vervets from scraping their heads on the trap mesh. In a different study at our field site, another female baboon was observed with a prolapsed rectum after feeding heavily on maize used as bait for trapping, but she was not trapped. A highly limited diet with foods low in water content and high in fiber, as is found in maize, can cause rectal prolapses (Taniguchi et al., 2019). Unexpected situations also arose that required us to make quick decisions or judgment calls. In the first such situation, an adult female vervet died in an open cage trap during the trap habituation period and left her very young infant orphaned. We decided to leave the infant with its mother because we had no way to care for it, and it died early the next day.

In the second situation, we chose not to avoid capturing lactating vervets. As the collars were to be worn for 1 year, and because vervets that reproduce annually can nurse their infants for up to 10 months (18 months for vervets that reproduce bi-annually; Lee, 1984), there was no guarantee that capturing females who had not yet given birth that year would not do so soon after as reproduction is seasonal and pregnancy is difficult to observe until very late. Indeed, in the two groups for which we have data on births, two of the four nonlactating females we collared subsequently reproduced that year.

Finally, we had initially thought it unnecessary to include weight-adding drop-off mechanisms to the collars as baboons and vervets were easily recaptured in other studies (Brett et al., 1982; Jolly et al., 2003) and we were also advised by primatologists and veterinarians with trapping experience to expect the same. Thus, we did not anticipate the development of trap aversion. Why the collared primates in our study became trap-averse is unclear, especially since ketamine induces amnesia (Haas & Harper, 1992). It is clear, however, that while uncollared individuals readily entered the traps again, the collared females remembered their initial trapping experience as long as 2 years later. As our goal was to trap two females per group, we always waited to capture the second female in a group before immobilizing the first. Perhaps the extra time in the trap before the ketamine was administered facilitated the formation of lasting negative memories. After our study was conducted, Cunningham, Unwin, and Setchell (2015) reported other researchers also having difficulty recapturing study subjects, which they suggested could have been a result of ketamine administration.

4.2 | Obvious and potential adverse outcomes of wearing the collars

An obvious adverse effect of the collars over the long term was the development of abrasions around the neck under the collar in one animal. We used one finger (always from a male capture team member) to check the fit of the collars, but two fingers are recommended by others (Ancrenaz et al., 2003). The fact that only one collared female in our study developed abrasions seems to indicate that our one finger measurement was sufficient in most cases.

A possible adverse effect of the collars was a significantly higher mortality rate of collared female vervets relative to their uncollared counterparts in the two habituated groups. The possibility exists that the greater mortality rate of collared female vervets was an artifact of small sample size (e.g., White & Garrott, 1990, pp. 30–35). It is also important to note that mortality while wearing GPS collars was certainly not inevitable, five vervets survived for 1–2 years before their collars were removed and two others whose collars could not be removed have survived and reproduced for more than 4 years. Nonetheless, it is useful to try to understand what caused the deaths of those collared vervets who did die.

One vervet died and was scavenged 39 days after collar deployment. Given the timing, it is possible that she died from complications caused by the collar. Three of the other four collared vervets died of leopard predation and we suspect that the fourth died of leopard predation as well (Isbell et al., 2018). This outcome is not surprising as many leopards live in the study area (Isbell & Bidner, 2016; O'Brien & Kinnaird, 2011) and leopards are a main predator of primates (Cheney et al., 2004; Cowlishaw, 1994; Hart & Sussman, 2005; Isbell, 1990, 1994; Jaffe & Isbell, 2010). We can think of two factors that might have interacted with the high density of leopards and compounded the vulnerability of collared vervets to leopard predation.

First, biases in trapping in favor of bolder individuals that are quicker to enter traps may increase vulnerability to predation among collared animals independent of the collars per se (Balaban-Feld et al., 2018; Geffroy, Samia, Bessa, & Blumstein, 2015; Hulthén et al., 2017). Multiple studies have reported a bias toward trapping bold individuals, i.e., those that take more risks under novel or threatening situations (Biro & Dingemanse, 2009; Garamszegi, Eens, & Török, 2009; Michelangeli, Wong, & Chapple, 2016; Wilson, Coleman, Clark, & Biederman, 1993), and bold individuals have also been found in some studies to be at greater risk of predation (Balaban-Feld et al., 2018; Hulthén et al., 2017).

Although we did not measure boldness in our study, we note that adult males in both species were the first to approach the traps in our study (see also Berger, 1970). In a different study, a large-scale trapping effort in which more adult male and fewer infant male olive baboons were captured on the first day of trapping than on later days (Brett et al., 1982) suggests that adult males are indeed bolder than adult females. We also note that all the female baboons we captured had sexual swellings, and may have been bolder in this reproductive phase. Such females show more proceptive behaviors toward males and often have close association with male consorts (Beach, 1976; Bercovitch, 1991; Matsumoto-Oda, 2002). They may also be bolder in approaching novel foods, such as the maize we used as bait, due to the presence of interested or consort males, which could reduce feeding competition with other group members.

In an assessment of personality in free-ranging vervets, those identified as bold by their behavior toward novel objects also approached and inspected snakes (Blaszczyk, 2017), a risky behavior as many snakes are predators of primates or kill them defensively (Headland & Greene, 2011; Isbell, 2006, 2009). The hypothesis that collars increase predation rates simply because the capture process is biased toward bold individuals remains to be fully tested, but until then, and practically speaking, future studies might consider it a possibility and avoid always capturing the first individuals to enter traps because they are, by definition, bolder than others.

It has also been suggested that collared animals may be more vulnerable than noncollared animals to predation if they move more slowly or are more noticeable to predators (Garrott, Bartmann, & White, 1985). The patterns we found, of significantly higher mortality of collared vervets relative to uncollared vervets in the two habituated groups with known individuals, and the absence of significant differences in mortality both between collared baboons and collared vervets and between collared and noncollared baboons in the habituated group with known individuals could be related to differences in movement or noticeability. During the year-long study, the two species suffered similar overall predation rates, but leopards killed vervets during the day and baboons at night (Isbell et al., 2018). If collars do make primates slower or more noticeable to predators, these effects would be more pronounced during the day when the primates are more active. For baboons, group-specific factors such as differential habitat use leading to differential exposure to predators may have also contributed to the deaths of collared females—both collared baboons that died were from the same (unhabituated) group. Of course, a trapping bias toward bolder individuals, slower movements, and greater noticeability will not be a concern where predators have been extirpated.

In conclusion, we agree with Jolly et al. (2003) that trapping primates can be easy but avoiding problems that can come with it can be challenging. Several reviews have proposed best practices for capturing, immobilizing, and collaring primates. These include (a) trapping early in the study; (b) using traps as small and as light as possible with rigid frames, flexible plastic-covered mesh walls, and no sharp edges; (c) sufficiently pre-baiting to accustom the primates to the traps; (d) minimizing the number of animals captured to only that needed for the study; (e) covering cages of captured animals when possible to reduce visual stimulation; (f) enlisting trained personnel to immobilize the animals; (g) wearing protective clothing, for example, gloves and face masks, while handling immobilized primates; (h) testing collars for signal transmissibility before deployment; (i) keeping collar mass as light as possible and aim for collars no heavier than 5% of the animal's mass; (j) including VHF transmitters and drop-off mechanisms on collars if the animal's mass allows them; (k) testing for collar tightness by placing two fingers under the fixed collar; (l) placing recovering individuals in quiet, shaded areas, with recovery cages covered to the extent possible (i.e., while still allowing for recovery monitoring); (m) monitoring their recovery, and; (n) releasing them within their home ranges (Ancrenaz et al., 2003; Cunningham et al., 2015; Honess & MacDonald, 2003; Jolly et al., 2003; Sikes & The Animal Care and Use Committee of the American Society of Mammalogists, 2016). Based on our own experiences, we also suggest that investigators (o) use as bait a variety of foods that are similar in quality (to minimize competition); (p) include an auto-release function on the collars, such as drop-off mechanisms, or, for smaller species, light-weight, biodegradable drop-off strips (e.g., Klegarth et al., 2017); (q) avoid capturing the first animals to go into traps to minimize potential bias toward bold individuals, who might be more vulnerable to predation; (r) document effects of the collars on primate movement; and; (s) publish both positive and negative outcomes of capturing, immobilizing, and collaring animals so that others in the future can be better prepared.

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CONFLICT OF INTERESTS

The authors declare that there are no conflict of interests.

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