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Research article

Behavioural evaluation of a meerkat *Suricata suricatta* group after insertion of deslorelin contraceptive implant in the dominant female

Helen Colbachini[1], Fabiana L. A. Padilha[1], Tatiana C. Silva[1], Laura C. Reisfeld[1], Paloma C. Henrique[1], Pedro N. Jorge-Neto[2,3] and Cristiane S. Pizzutto[2,3]

[1]Aquário de São Paulo, São Paulo, SP, Brazil
[2]Department of Animal Reproduction, Faculty of Veterinary Medicine and Livestock, University of São Paulo, São Paulo, SP, Brazil
[3]Instituto Reprocon, Campo Grande, MS, Brazil

Correspondence: Helen Colbachini, hcolbachini@gmail.com

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Abstract

Meerkats *Suricata suricatta* are animals that live in groups and have a reproductive cooperation system. Their high reproductive rate in ex-situ conditions can often be a problem for the supporting institution and, therefore, the use of an effective contraceptive method is necessary. The objective of the present study was to evaluate the effectiveness of a contraceptive implant placed only on the dominant female of a group of meerkats and its effect on stability of the behaviour and social hierarchy of the group. The alpha female received a 4.7 mg deslorelin acetate implant (Suprelorin, Virbac) in week 8, and the group's behaviour was observed in two distinct stages: Stage 1, before implantation (first 8 weeks); and Stage 2, after implantation (between 13 and 21 weeks). There were no births in this interval, and the social hierarchy and intra-group relations remained stable. Agonistic behaviour, present in Stage 1, showed a significant reduction in Stage 2. The results show that use of a deslorelin contraceptive implant only in the dominant female was efficient for reproductive control in a meerkat group with few subordinate females. After 12 months of implantation, an ultrasound examination showed the presence of follicles in the ovaries, signalling a possible return of reproductive activity. Further studies should be performed to better understand the long-term effect of the contraceptive implant in meerkats and other species with matriarchal societies and cooperative behaviours.

Introduction

The meerkat *Suricata suricatta* is a small mammal of the Herpestidae family. It is currently classified as Least Concern in terms of its risk of global extinction (Jordan and San 2015).

As a specialised cooperative breeder—known as eusocial—the dominant meerkat female produces greater than 75% of the group's offspring (Clutton-Brock 2006; Young et al. 2006). The subordinate females are reproductively suppressed, mainly due to stress and aggressive behaviours of the dominant female towards them. This aggression is more intense during the dominant female pregnancy, and can even result in the eviction of subordinates from the group. Evicted subordinate females will not return until parturition of the dominant, when they will cooperate in raising the pups (Young et al. 2006).

Meerkats are considered important animals for environmental education about the illegal wildlife trade and the responsibilities of exotic pet owners. However, these animals can have limited value for current conservation (Kubiak and Saunders 2016). Zoos often find uncontrolled reproduction of this species undesirable, and population growth with risk of evicting subordinate members can become a problem. In this context, contraception to control the reproduction rate is a viable and potentially practical tool for controlling in-situ and ex-situ populations (Bertschinger and Caldwell 2016). However, many contraceptive methods are experimental in wild animals, as they were developed for domestic animals (Asa et al. 2014, Cowl et al. 2018).

Some fundamental characteristics of contraceptives in wild animals, such as safety, reversibility, and reduced impact on

reproductive behaviour, have been reported by Rosenfield and Pizzutto (2018). Based on scientific reports in wild animals, using deslorelin implants in zoos has become more frequent in species with strict social hierarchies (Asa and Moresco 2019, AZA Small Carnivore TAG 2011).

The endocrine reproductive system is controlled by communication from the hypothalamus to the pituitary gland and from the pituitary gland to the gonads. The most important hormone is the gonadotropin-releasing hormone (GnRH), synthesised in the hypothalamus, which controls the synthesis and release of the luteinising hormone (LH) and the follicle stimulating hormone (FSH) from the pituitary gland. These are responsible for the synthesis of sex hormones, such as estrogen and testosterone, which are the driving force of gonadal activity, the development of secondary sex characteristics and behaviour, and other physiological functions (Rosenfield et al. 2016).

Deslorelin acetate implants function by causing a down-regulation of GnRH receptors after an initial 3–4 week stimulation of the reproductive system, during which oestrus and ovulation occur in females and testosterone and spermatogenesis increase in males. This results in inhibition of the synthesis and secretion of both pituitary gonadotropins, LH and FSH, leading to a suspension of cyclic ovarian activity in females (D'Occhio et al. 2000, Ortmann et al. 2002) and spermatogenesis in males (Kubiak and Saunders 2016).

Despite the increased frequency in use of deslorelin implants, individual behavioural aspects have not been analysed in depth in some species that have already been tested with GnRH agonists, such as African wild dogs, leopards, cheetahs (Bertschinger et al. 2001), African lion (McEvoy et al. 2019), and meerkats (Kubiak and Saunders 2016), signalling the importance of studying this in association with reproductive control. Therefore, the objective of the present study was to assess whether contraceptive implantation in only the dominant female of a meerkat group is a safe method that guarantees both the effectiveness of contraception and stability of behaviour and the social hierarchy.

Materials and methods

This experiment was conducted at Aquário de São Paulo (São Paulo, SP, Brazil; 23°35'36.5" S 46°36'51.1" W) between November 2015 and July 2016. The study followed Brazilian laws (IBAMA IN 07/2015) and was approved by technical staff from the Aquário de São Paulo.

Animals and experimental design

A group of reproductively mature meerkats was used, with all individuals aged over 30 months and weighing between 1.0 and 1.5 kg. The colony (n=5) had a male-female dominant couple, two submissive males and a submissive female (non-related animals). The group was formed in February 2014, and no sign of a dispute over a change for dominance—defined by zookeepers through behavioural observation of the group—had been identified before contraception. The dominant female had been reproductively active since June 2014, resulting in 5 different litters (one in 2014, three in 2015 and one in 2016, during the observation period but before implantation). The studied group was housed next to another group of meerkats (the second group was not observed), and sometimes they could interact indirectly (visually but not physically).

Contraceptive implant application

All animals were removed from the enclosure and transported inside a pet crate to the veterinary area. The dominant female was physically restrained using leather welding gloves, and chemically immobilised with ketamine (10.0 mg/kg; im; Quetamina, Vetnil, SP, Brazil) combined with midazolam (0.5 mg/kg; im; Dormire, Cristália, SP, Brazil). After postural reflex was no longer evident, the dominant female was weighed, and anaesthesia was maintained using 1% isoflurane (Isoforine, Cristália, SP, Brazil). One Suprelorin 4.7 mg implant (Virbac S.A., France) was placed subcutaneously in the loose skin between the shoulder blades. This procedure was performed at the end of the eighth week of observation. The 4.7 mg implant is expected to have a minimum duration of 6 months.

The dominant female was reinserted in the crate with the other meerkats as soon as she recovered from anaesthesia. The animals

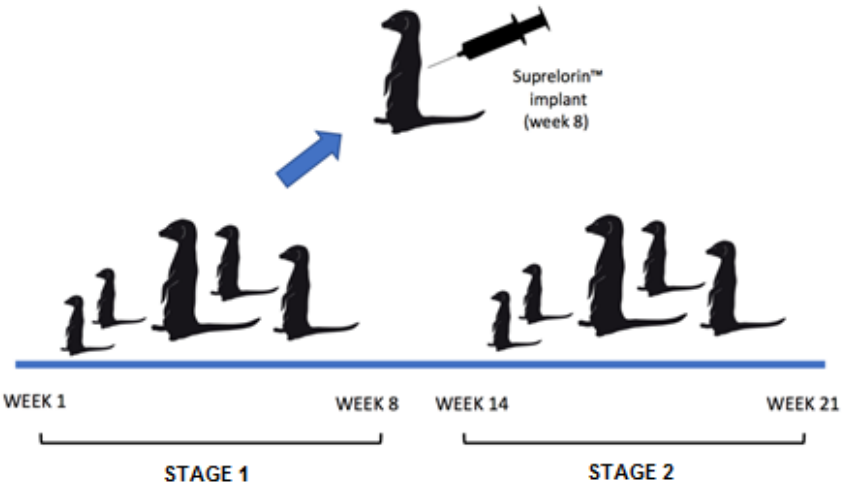

Figure 1. Stages of behavioural observations of meerkat group before and after the dominant female's deslorelin implant.

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Table 1. Definition of categories and behavioural acts observable in meerkats kept in ex-situ conditions.

Behaviour categories	Behavioural acts
Social interaction	Play-biting: animals nibble at each other, stand up on their hind legs and grasp each other with the forepaws, fall over and break loose and chase each other hither and thither (Ewer 1963).
	Scratching each other: animals scrape each other with their forelegs discontinuously, often interspersed with other affiliate behaviours.
	Group cleaning: one animal approaches the other and nibbles it with the incisors; the latter reciprocates the behaviour (Ewer 1963).
	Social marking behaviour: one animal rubs their cheek against the other individual.
	Smelling: one animal approaches the other and sniffs it.
	Licking: one animal approaches the other and rubs it with the tongue.
	Following: one animal approaches another individual and follows it.
	Courtship: interaction behaviours between males and females for reproduction, including neck grip (not closing jaws sufficiently to wound the other animal) or nipping on the cheeks (Ewer 1963).
	Mating: one animal approaches another individual and grasps it around the body with its forepaws (mount; Ewer 1963).
	Copulation: male mounts female and introduces its reproductive organ into female's reproductive tract.
Agonistic behaviour	Threaten attack: animal presents piloerection, legs extended, back arched, tail erected, and head slightly lowered while observing the other animal (Ewer 1963).
	Chase: animal runs down another individual, growling and trying to bite.
	Showing teeth: animal's jaws are kept tightly closed, revealing the teeth; the head is darted forwards towards the other animal, and at the same time, it can be moved rapidly from side to side (adapted from Ewer 1963).
	Lift the tail: the animal's tail is held stiffly erect (Ewer 1963).
	Startle itself: the animal approaches the enemy, tail lifted, and slowly moves backwards while jumping (Ewer 1963).
	Submissive behaviour: lowering the head to the other animal.
	Aggressive bite on another individual: animal bites another individual and at the same time moves its head rapidly from side to side.
Agonistic behaviour	Rubbing anal gland: one of the animal's hind legs is slightly raised, so the rectal wall becomes everted to expose the openings of the anal gland; then the animal scrubs it against stones, objects or the floor (Ewer 1963).
	Rubbing the cheek: one animal approaches stones, objects or the floor and scrubs its cheek on it.

were observed, and no demonstration of agonistic behaviour was noticed until after the animals returned to the enclosure. Twelve months after the implant, the female was chemically restrained and an ultrasound exam (Esaote MyLab Delta Vet with linear transducer SL1543, 13–4 MHz and 47 mm) was performed for monitoring of the uterus and ovaries.

Behavioural observation

Two stages (Figure 1) comprised the group's behavioural observations: Stage 1, control (dominant female without implant, first eight weeks) and Stage 2, medium-term post-implantation (possible hormonal suppression by the implant, between 13 and 21 weeks). Since the focus of the study was to observe the social and hierarchy effects of the contraceptive implantation of only the dominant female of a meerkat group, the stimulation period caused by the introduction of the implant was removed from the study.

All animals were individually identified through natural marks. The behaviour of each individual was recorded by instantaneous focal sampling every one minute (Altmann 1974, Colbachini et al. 2020, Lehner 1998). The animals were observed in daily sessions of one hour, with 20 h of observation in each stage, totalling 40 h. The observation period was selected during the group's activity peak between 9 am and 4 pm, and the time of observations was balanced between the two stages of the study.

Regarding behaviour classification (Table 1), three categories were defined based on zookeepers' previous observations and those established by Ewer (1963) and Clutton-Brock et al. (2006). "Social interaction", "agonistic behaviour", and "marking" have been established as categories of interest for identifying signs of intra-group reproductive conflict, as well as social hierarchy instability (Kutsukake and Clutton-Brock 2006). Therefore, the frequency of occurrence of these behaviours was compared between the two stages.

Statistical analysis

All data were analysed using Program R (R Development Core Team 2011). Data normality was assessed by the Shapiro-Wilk normality test and, since the data are non-parametric, they were subsequently tested for their differences using the Wilcoxon signed-rank test (Zar 2010). From the data, it was possible to infer the frequency of occurrence of the observed behaviour categories "social interaction", "agonistic behaviour", and "marking" in both study stages (in this first analysis both sexes were included). It was also possible to infer from the individual social interactions of both females the percentage of interaction with each of the other individuals in the group. Only the situations in which the female was the agent of the interaction (regardless of whether or not there was reciprocity in the behaviour) were considered. Females were evaluated separately due to the greater risk of the subordinate female attempting to achieve dominance of the group. However, interactions between females and males were recorded when females were the agents of the interaction.

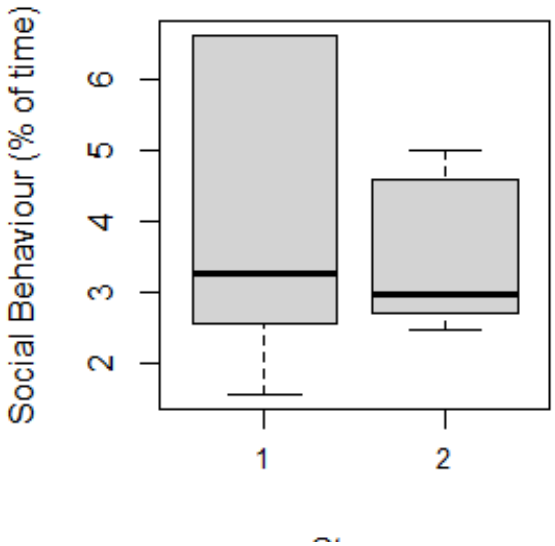

Figure 2. The difference in the percentage of time spent on social interactions in the group of meerkats during contraception of the dominant female. Stage 1 corresponds to the control (animals without hormonal changes) and Stage 2 refers to the probable phase of hormonal suppression.

Figure 3. The most frequent social behaviour performed by the meerkat group: group cleaning (one animal approaches the other and nibbles it with the incisors, the latter then reciprocates the behaviour).

Figure 4. The meerkat group's most frequent agonistic behaviour is lifting the tail (the animal's tail is held stiffly erect).

Results

During the study period, there were no births nor breeding behaviour in the group. Courtship behaviour from subordinate males toward the subordinate females was seen just once, but this social interaction was then interrupted. No courtship behaviour toward the dominant female was observed, however, the animals showed submissive behaviours to her.

There was no overall change in the frequency of occurrence of social interactions in the meerkat group (Wilcoxon signed-rank, P=0.4375; Figure 2), with a mean of 3.87% of the time spent on these behaviours. Group cleaning was the most frequent social behaviour in both stages (with an occurrence of 76.46% of social behaviour in Stage 1 and 50.45% in Stage 2; Figure 3). There were also no changes in group scent-marking behaviour (Wilcoxon signed-rank, P=0.1814) nor in interactions between the dominant female and all other individuals (Wilcoxon signed-rank, P=1) and between the subordinate female and the others (Wilcoxon signed-rank, P=1).

In both stages, the dominant female interacted most with the dominant male, representing 69.13% of the total of the dominant female's interactions in Stage 1 and 75.00% in Stage 2. The subordinate female also maintained consistency in the individual with whom she most frequently interacted; the dominant female was responsible for 41.93% of the subordinate female's interactions in Stage 1 and 38.88% in Stage 2. The dominant female interacted least with subordinate males in Stage 1 (2.47% and 3.70% of interactions) and with one of the subordinate males (3.57%) and the subordinate female (7.14%) in Stage 2. The subordinate interacted least with the dominant male in both stages (3.22% of interactions in Stage 1 and 11.11% in Stage 2).

On the other hand, the frequency of occurrence of agonistic behaviours showed a decreasing trend (Wilcoxon signed-rank, P=0.0625). Despite this, the frequencies of group agonistic behaviours were low in both stages, with the behaviour "lift the tail" being the most frequent in both stages (with an occurrence of 100.00% of agonistic behaviours in Stage 1 and 66.66% in Stage 2—the only other agonistic behaviour displayed in this stage was "startle itself"; Figure 4). In Stage 1, the dominant female displayed the highest frequency of agonistic behaviour, with a total of 1.72% of the time spent in these behaviours; the dominant male presented the second highest frequency (1.39%), followed by subordinate males (0.90% and 0.81%) and, lastly, the subordinate female (0.32%). Moreover, in Stage 2, the dominant female again presented the highest frequency, representing 0.16% of the time (Figure 5); this same frequency was observed in one of the subordinate males. The dominant male and the subordinate female displayed agonistic behaviours only 0.08% of the time, and the other subordinate male did not display any agonistic behaviour in Stage 2.

On ultrasound examination performed 12 months after implantation, no changes were observed in the uterus. However, follicles were present in the ovaries.

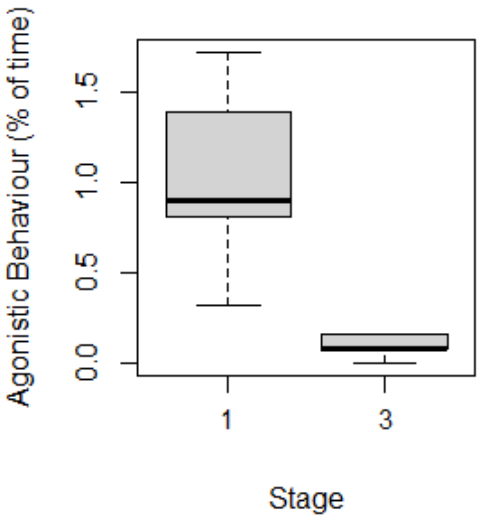

Figure 5. The difference in the percentage of time spent on agonistic behaviours in the group of meerkats during the contraception process of the dominant female. Stage 1 corresponds to the control (animals without hormonal changes) and Stage 2 refers to the probable phase of hormonal suppression.

Discussion

Deslorelin implants have previously been used as a contraceptive method in all meerkats of the same group (Kubiak and Saunders 2016). To the best of our knowledge, the present study is the first to show success in reproductive control using a deslorelin implant only in the dominant female of a group while also including an assessment of social and behavioural interactions.

As a frequently breeding species in zoos worldwide, reproduction by meerkats may be undesirable and population growth may become a problem (Kubiak and Saunders 2016), due both to increasing demand for space and the difficulties of dealing with tension within a social group. At the same time, the maintenance of viable ex-situ populations is a necessity encompassed by the One Conservation concept (Pizzutto et al. 2021). Therefore, an understanding of the reproductive (Silvatti et al. 2020) and behavioural (Young et al. 2006) aspects of meerkats are essential for developing effective strategies for population control and managing tension within social groups. Studies related to meerkat reproductive management must be provided to allow better ex-situ management of the species.

Several studies have evaluated the reproduction frequency of subordinate meerkat females (Bell et al. 2014, Clutton-Brock et al. 2008, Kutsukake and Clutton-Brock 2008, O'Riain et al. 2000), indicating that the dominant female will always try to monopolise reproduction (Bell et al. 2014, Kutsukake and Clutton-Brock 2006, Young et al. 2006). Pregnancy cases in subordinates are related to failures in reproductive suppression (Kutsukake and Clutton-Brock 2006) or occur where the reproductive success of the dominant female will be minimally affected by the pregnancy of another female in the group (Bell et al. 2014).

Clutton-Brock et al. (2008) observed that the breeding frequency of subordinates declines with increasing group size. Since this studied group is formed of only five individuals and only the dominant female was implanted, it could be an inefficient way to control reproduction of the group as a whole. Despite this, previous indications of the reproductive absence of the

subordinate female were strong indicators that the dominant female would continue to suppress the reproduction of the subordinate female as she was the only one in the group that would assist in caring for the dominant offspring, corroborating with Bell et al. (2014). So we hypothesised that the dominant female would still suppress the subordinate as she was the only other female of the group. After Stage 2, males from a neighbouring group showed courtship toward the subordinate female. However, no mating nor copulation was observed within the study group. This suggests that the subordinate female continued to have reproductive potential, but the dominant female maintained her reproductive suppression. This result corroborates with the conclusion of Clutton-Brock et al. (2008), in which the breeding frequency of a subordinate female is related to the benefits that the dominant female receives in suppressing the subordinate's breeding. Thus, this study indicates that it may be possible to decrease the costs of reproductive control using deslorelin implants only in the dominant female in groups with few subordinate females.

This study is the first case report that includes a detailed analysis of behavioural effects after deslorelin implant in meerkats. Other research suggests that there is no behavioural nor hierarchical effect in groups of felines, canids (Bertschinger 2011), and meerkats (Kubiak and Saunders 2016), corroborating our results. In the latter study, only reproductive activity and dominance were observed. However, the present study evaluated female individual interactions as well as other behavioural categories and our results indicate that although maintenance of dominance does occur, there is a possible behavioural effect in the group: agonistic behaviours may decrease in the probable hormonal suppression phase.

Deslorelin implantation has been described to decrease aggression in other species (Cowl et al. 2018, Molter et al. 2015, Raines and Fried 2016, Vinke et al. 2008). However, this is the first time it has been indicated in meerkats. Meerkats are animals known for their dominant behaviour, and the use of aggression is recurrent to maintain the social hierarchy (also guaranteeing an increase in the individual's fitness). As a result of this behaviour, the eviction of individuals from the group is frequent (Bell et al. 2014, Clutton-Brock et al. 2008, Kutsukake and Clutton-Brock 2006, Kutsukake and Clutton-Brock 2008). The eviction of subordinate individuals is a significant problem for populations under human care due to space limitations (Seal 1991), and it is difficult to find acceptable social strategies for surplus animals (Kirkpatrick and Turner Jr. 1991). This eviction is a consequence of accumulated aggression by the dominant female (Kutsukake and Clutton-Brock 2006). The probable decrease in the frequency of agonistic behaviour generated by hormonal suppression of the dominant female would appear to be a potential strategy for social stabilisation in groups of meerkats. More studies are needed to prove this effect on the aggressiveness of meerkats, to generate conclusions about whether this would be a practical strategy to avoid future eviction of individuals when they mature and to guarantee the well-being of the entire group.

Behavioural observations were performed over approximately 5 months, but the zookeepers continued monitoring daily for 12 months. Even without performing the ethograms throughout this period, the efficiency of the contraceptive was confirmed, without the occurrence of births and with maintenance of the group's social structure and no change in dominance. At the end of the twelfth month, an ultrasound examination was performed, showing the presence of follicles and suggesting a possible return of reproductive activity.

To have adequate reproductive control and maintain genetic diversity, especially in species with similar characteristics, understanding the best contraceptive technique is essential. As suggested by Rosenfield and Pizzutto (2018), reproductive control of wild animals under human care should ensure that: the number of individuals in a group is maintained, contraception is reversible, the social and behavioural stability of the group is maintained, there is a low financial cost for the institution, and the welfare of the animals is ensured. It is important to note that this study considers only one group of meerkats, and further studies should be done to ensure that this pattern is repeated in other groups. Although not scientifically analysed, the second group of meerkats (with five females and seven males) from Aquário de São Paulo had their dominant female implanted a few months later, and no pregnancy nor change in social hierarchy was reported (personal observation). A better understanding of the long-term effect of contraceptive implantation in meerkats is also needed, as well as in other species with matriarchal societies and cooperative breeding behaviours.

Conclusion

Considering the consolidated data, using a deslorelin implant only in the dominant female is effective for reproductive control of a group with few subordinate females. This method did not change the group's social hierarchy and may result in a possible decrease in agonistic behaviours in the group for at least 12 months.

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