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Camera trap-based sex-specific behavioural thermoregulation observations of the Ratel (Mellivora capensis)

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Short Report

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Abstract

Thermoregulation of body temperature to cope with the environmental harsh conditions varies according to species, age, and sex. Females and males body temperature regulation strategies vary either physiologically or biologically, as it depends on peripheral and central thermoreceptors. Brown adipose tissue (BAT) helps females tolerate thermal stress easily. Although physiological mechanisms such as vasodilation contribute to cooling, behavioural responses often provide the fastest and most effective means of dissipating heat under natural conditions. But species also take help from external sources, such as water or mud. This study demonstrates the sex-specific thermoregulation of the Ratel (*Mellivora capensis*) through camera trap-based observations. We observed the frequent submerging behaviour of the male in water, whereas the female stayed outside during the peak summer and the breeding phase of the Ratel.

Introduction

In dry and semi-arid landscapes where high ambient temperature and limited water availability impose substantial physiological stress, water is essential for survival. It plays a very critical role in shaping the movement and behaviour of many terrestrial mammals. Beyond hydration, water bodies function as important microhabitats for behavioural thermoregulation, allowing animals to dissipate excess body heat during periods of thermal stress (Valeix et al., 2008; Fuller et al., 2016). Animal taxa have evolved to survive in such harsh conditions. Mammalian taxa shape themselves accordingly, with less urination, spending daytime in burrows to escape heat stress, and spending daytime inside water bodies to escape heat stress and fulfil thermoregulation requirements, particularly during the dry season when temperatures are higher, and surface water is limited. Activity concentration around water sources functions as an important microhabitat for hydration and thermoregulation (Boyers et al., 2019; Blank and Li, 2022). This also influences the biological behaviour of the species, such as activity pattern, activity budget and space utilisation, especially during the sensitive periods such as reproduction, when males and females may exhibit different energetic demands. In colder conditions or cold-blooded animals, they need external heat to activate themselves, which costs less metabolic energy. Various animals have evolved various techniques to cope with the temperature-related environmental stress, such as Tiger (*Panthera tigris*) sitting in water, crocodiles, and turtles basking in the sun, rodents, monkeys and lemurs hunched, sitting, protecting from the hypothermic and hyperthermic conditions (Terrien et al., 2011). These behaviours vary considerably among species, and they are also sex-specific, reflecting differences in morphology, physiology, endocrine regulation and reproductive investment. During reproduction, males and females may experience different energetic demands, where females tend to exhibit greater thermal tolerance and different thermoregulatory thresholds than males. In contrast, males often invest more in courtship, territorial defence and mating activities, which leads to an increase in metabolic heat production. Consequently, particularly under hot climatic conditions, the behavioural mechanisms that facilitate heat dissipation may differ between the sexes (Alonso et al. 2016).

The role of behavioural thermoregulation during reproductive interactions remains largely unexplored, despite the growing knowledge of mammalian thermoregulation, particularly in cryptic carnivores, where direct sightings and behavioural observations are inherently difficult. We propose that reproductive activities may involve significant thermal demands, especially under high ambient temperatures, requiring behavioural mechanisms to dissipate heat. We further hypothesise that these thermoregulatory responses may differ between the sexes because of differences in reproductive investment, endocrine physiology, metabolism, body morphology and behavioural ecology, including energy involvement differences in reproductive activities by males and females. Such sex-specific behavioural adjustments may represent an overlooked component of mammalian reproductive ecology and could be widespread among mammals, but remain undocumented due to logistical challenges of observing cryptic species (Zub et al., 2013; Fernández-Peña et al., 2023).

The Ratel (*Mellivora capensis*) is a cryptic mustelid inhabiting arid and semi-arid environments, and represents an ideal species for investigating behavioural thermoregulation under natural conditions. The thermoregulatory behaviour, particularly during the breeding season, lacks scientific documentation owing to its elusive nature and predominantly nocturnal activity. We documented repeated water use by male-female Ratel pairs during the reproductive period through long-term camera trap monitoring. These observations led us to hypothesise that water use during this period may represent a behavioural thermoregulatory response to elevated thermal and energetic demands associated with reproduction. We further propose that sex-specific physiological and behavioural differences may contribute to the contrasting patterns observed between males and females. By presenting this hypothesis, our study provides a new perspective on behavioural thermoregulation in cryptic carnivores and encourages future investigations into similar responses across other mammalian species (Begg et al., 2003).

Materials and Methods

Study area

The study was conducted in Mitiyala Wildlife Sanctuary, situated in Amreli district, which comprises 18.22 km^2. This site is currently harbouring the Asiatic lion (*Panthera leo persica*), the Indian Leopard (*Panthera pardus fusca*) as large carnivore and Chital (*Axis axis*), Nilgai (*Boselaphus tragocamelus*), Sambar (*Rusa unicolor*), Four-horned Antelope (*Tetracerus quadricornis*) and Wild Boar (*Sus scrofa*) as herbivores. The dominant vegetation type is Dry deciduous forest, where woodland comprises *Senegalia senegal, Butea monosperma, Azadirachta indica, Diospyros melanoxylon and Vachellia nilotica.* Mitiyala Wildlife Sanctuary provides good escape cover with dense shrub cover of *Ziziphus nummularia* and *Lantana camara* for the cryptic species such as Ratel. Mitiyala have ten artificial water points functional during the summer season for the wild animals (Kaushal et al., 2026).

Methodology

We systematically deployed Cuddeback camera traps (white flash C1 and motion sensor infrared camera H20IR) at the water points to assess the importance of the water points during the summer season. We set camera traps at FAP mode to function 24 hours/day and capture a video after three consecutive images with a trigger delay of ½ seconds. The camera traps were placed at a height of 30-40 cm above ground, parallel to the surface to maximise the detection of both small and large mammals (Glen et al., 2013; Eliades et al., 2022; Krag et al., 2023; Fink and Jachowski, 2025). Images and videos were used to assess species composition, visitation frequency, temporal activity and behavioural interactions at water sources. For each Ratel detection, we noted the number of individuals, sex (from external morphological features), arrival sequence, behavioural activities (drinking, water immersion, movement, etc.), and duration of water use (Smith et al., 2024). Independent events were classified as consecutive detections of the same individuals separated by at least 30 min in the absence of continuous recording. If the same pair stayed at the water point, then continuous images and videos during a single visit were treated as one behavioural event, irrespective of the number of photographs recorded (Smith, 2025).

Result

During a camera trap survey, camera observations recorded the repeated frequent visit of Ratel pairs to artificial water points during the Ratel's breeding season (May-June), although the mating period is throughout the year, the pair was established in the sanctuary in April, based on the camera trap detections. In multiple independent events, the male consistently exhibited prolonged physical contact with water by entering through and remaining partially or almost completely submerged (Fig. 2). In several observations, only the head or upper dorsal region remained above the water surface, indicating substantial body immersion. Although complete immersion was not always captured because of the camera trigger interval, males frequently emerged with visibly wet pelage, and the wet concrete wall of the water point further suggested the individual was recently fully immersed in water.

In contrast, the accompanying female did not exhibit comparable immersion behaviour. Females generally remained outside the water or at the edge of the trough while the male was immersed. Drinking behaviour was observed in both sexes; however, repeated body immersion was consistently associated with males at a higher frequency, such as visiting every two hours. The immersion was documented during both nocturnal and diurnal phases, indicating that it was not restricted to a particular time of the day. Across observations, females did not display similar behaviour under comparable environmental conditions and time (Fig. 2).

These observations demonstrated a clear sex-specific difference in the use of water bodies during the breeding season, where males exhibited immersion behaviour, while this behaviour was not observed in the females.

Discussion

Behavioural thermoregulation is a crucial mechanism that enables mammals to maintain their body temperature within a physiological optimal range when external environmental temperatures exceed the thermoneutral zone. Instead of depending exclusively on autonomic responses, many mammals mitigate thermal stress by employing behavioural adjustments that increase heat dissipation, such as seeking shade, occupying burrows, reducing physical activity and immersing in water. These behaviours become significant in dry and semi-arid regions during the summer, when ambient temperatures may exceed the effectiveness of the standard physiological cooling process (Fuller et al., 2016; Verzuh et al., 2023).

Our camera trap data observations show that water immersion may represent an additional previously overlooked component of behavioural thermoregulation associated with reproductive behaviours in Ratel. During repeated observations of mating pairs, males were found consistently entering and immersing themselves in water immediately following pair-associated interactions, whereas females generally remained outside the water. Because observations were frequently recorded across independent events, the behaviour appears unlikely to be incidental and instead reflects a sex-specific behavioural response. One possible explanation could be that reproductive activity imposes unequal thermal and energetic demands on the two sexes. In mammals, males often exhibit greater physical activity during courtship and copulation, including mate searching, prolonged pursuit, competition and repeated mating attempts, all of which increase metabolic heat production. Increased muscular activity invariably elevates body temperature, necessitating effective heat dissipation to restore thermal homeostasis. Water immersion provides rapid conductive and convective heat loss and may therefore represent an efficient behavioural strategy for reducing post-reproductive heat load (Pilakouta and Baillet, 2022).

The noted behavioural difference may also indicate fundamental physiological differences between males and females. Empirical research in mammals has demonstrated sex-specific thermoregulatory responses, with females often tolerating thermal stress differently due to hormonal regulation, reproductive hormones and body composition, as Brown adipose tissue (BAT) helps females to tolerate thermal stress easily. Hormonal differences, particularly the influence of sex steroids on hypothalamic thermoregulatory pathways, shift thermal response thresholds and alter behavioural responses to heat. Consequently, males and females may not possess identical thermopreferenda, resulting in different behavioural strategies for maintaining thermal balance (Alonso et al., 2016).

Thermal activity is continuously monitored by peripheral and central thermoreceptors, which relay signals to the preoptic area of the hypothalamus. When body temperature rises beyond optimum levels, the hypothalamus triggers thermolytic responses aimed to accelerate heat loss while reducing further heat production. Although physiological mechanisms such as vasodilation contribute to cooling, behavioural responses often provide the fastest and most effective means of dissipating heat under natural conditions. In semiarid ecosystems where free water sources are limited, immersion in water may consequently constitute a very effective thermoregulatory behaviour (Gagnon and Kenny, 2012). An additional factor that may contribute to the observed male behaviour is the cumulative physiological stress associated with reproduction under high ambient temperatures. Heat generated from muscular

activity, elevated metabolic rate, and endocrine activation may increase thermal load beyond the capacity of passive cooling processes. Under these circumstances, behavioural immersion could reduce the risk of acute hyperthermia while facilitating recovery after reproductive activity. Although endocrine parameters such as testosterone could theoretically influence aggression, activity level or metabolic heat production, our observations do not directly evaluate hormonal mechanisms, and therefore these remain hypotheses requiring physiological investigation (Gudka et al., 2019).

Because Ratel are among the least-studied species and direct observations of reproductive behaviour are exceptionally rare, documenting such behaviours is intrinsically difficult. Camera trapping, therefore, provides a unique opportunity to detect behaviours that are otherwise missed in cryptic mammals. Similar thermoregulatory responses may occur in other carnivores but remain unrecorded and undocumented because reproductive behaviour is rarely studied under natural conditions. Our study does not demonstrate the physiological mechanism responsible for water immersion; rather, it identifies a consistent behavioural pattern that generates testable hypotheses. We propose that post-reproductive water immersion functions as sex-specific behavioural thermoregulatory mechanisms in Ratels, with males demonstrating greater dependence on water-mediated heat dissipation than females. Further studies integrating behavioural observations with environmental temperature, body temperature, endocrine factors and activity data will be necessary to evaluate this hypothesis across Ratels and other mammalian species.

Abbreviations

IR- INFRARED

FAP- Fast as Possible

cm.- centimeters

km- kilometers

min- minutes

Declarations

Ethics Approval and Consent to Participate

This study employed non-invasive camera trapping without the use of bait, scent lures, or attractants. Animals were neither captured, handled, nor disturbed during the study; therefore, ethical approval was not required. Permission to conduct the study was granted by Chief Wildlife Warden (**WLP/RTC/TE-1/C/725-26/2023-24)**.

Consent for Publication

Both authors consented for the publication of this manuscript.

Availability of data and material

The authors declare that no supplementary material is attached to this manuscript.

Competing Interest

The authors declare no conflict of interest.

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Authors' Contribution

S.K.K. prepared the first draft of manuscript, A.M.K. supervised this study and reviewed the first draft. S.K.K. edited the final draft. Both authors read, reviewed, and edited the final draft.

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Figures

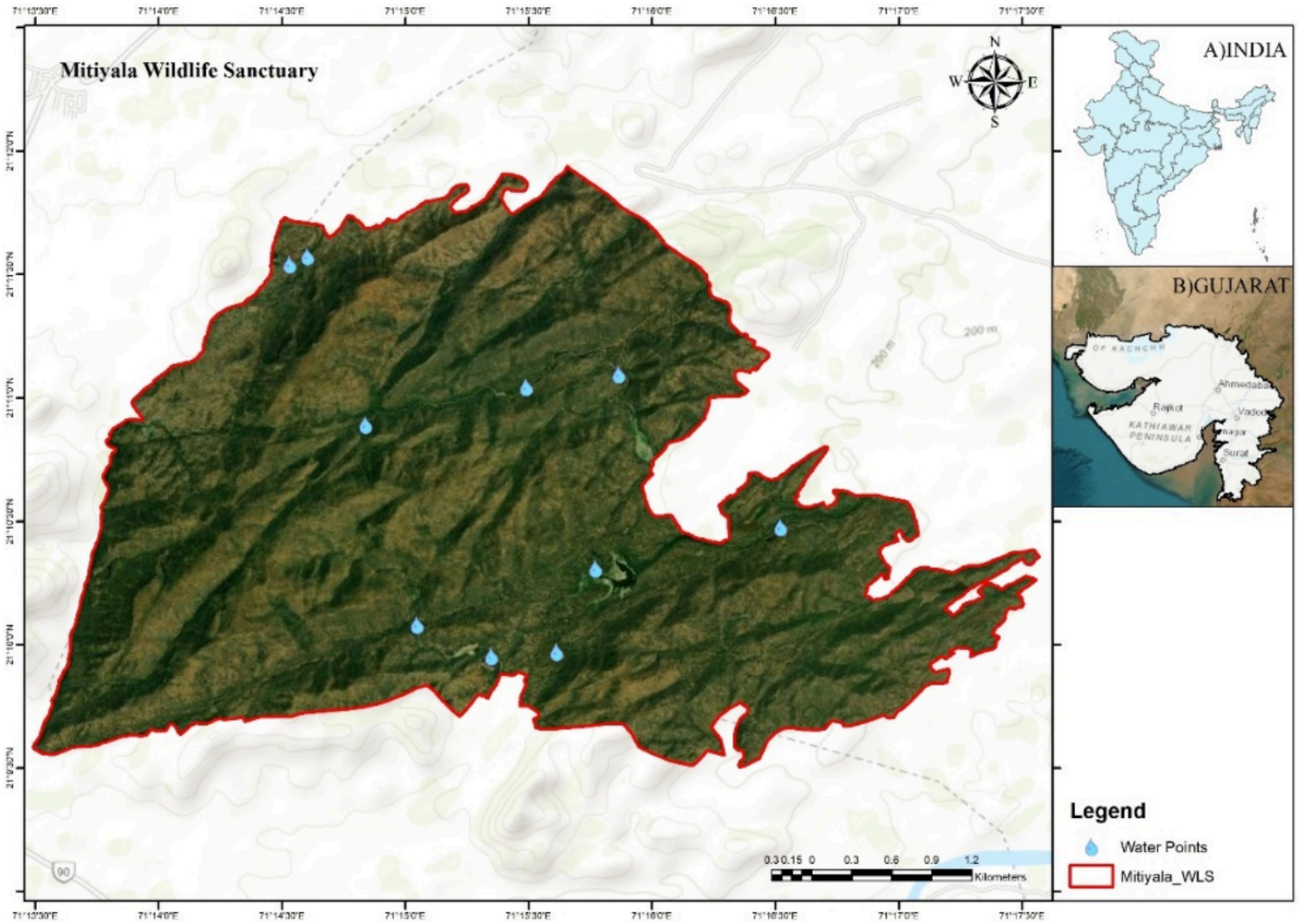


Figure 1

Mitiyala Wildlife Sanctuary with the distribution of monitored water points. Map insets A) India and B) Gujarat



Figure 2

Camera trap sequence images showing repeated water immersion behaviour by male Ratel (Mellivora capensis) at the monitored water point during the breeding season in Mitiyala Wildlife Sanctuary