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Short Communication

The Use of Spool Tracking Technique to Monitor the Movement of Juvenile Asian Water Monitor Lizard

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ABSTRACT
Tracking animal movement is essential for conservation but often financially challenging. This study tested a low-cost spool tracking method using juvenile Asian water monitors (*Varanus salvator*) housed in a dome enclosure. Tail-mounted spools were more effective than back-mounted ones, allowing greater movement and fewer complications. Lizards were active during the day, preferred vegetated microhabitats, and often basked or soaked. Importantly, tail-mounted spools caused no injuries or entanglement, indicating this method is a viable, non-invasive option for monitoring juvenile lizard movement in resource-limited contexts, with potential application to other species.

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Understanding animal movement is fundamental for studying ecology and behaviour, both of which are vital for effective wildlife habitat and corridor management (Allen & Singh 2016). However, tracking animal movement remains a significant challenge (Kernohan et al. 2001). Researchers have developed a wide range of methods, from direct observational techniques (Altmann 1974) and mark-recapture studies (Lagrange et al. 2014) to sophisticated technologies such as radio telemetry, GPS tracking, RFID chips, geotags, radiolocation devices, and even georeferenced social media data (Rutz & Hays 2009; Benson 2010; Cagnacci et al. 2010; Kays et al. 2015; Miller et al. 2019; Gracanin & Mikac 2022). While these tools have greatly advanced our capacity to monitor wildlife, they are often prohibitively expensive and difficult to access, particularly in biodiversity-rich regions with limited financial and logistical resources. As more accessible alternative, spool tracking—which involves attaching a spool of thread to an animal—provides a simple yet effective method for monitoring the fine-scale movement of small animals over short distances (Sutherland et al. 2008).

Monitor lizards (*Varanus* spp.) among the largest members of the Varanidae family, are known for their relatively slow movement compared to other lizards (Bennett 1995). These reptiles are primarily diurnal becoming active in the morning to forage and bask and resting at night (Imansyah et al. 2007). Adults often seek shelter under trees, in burrows, or within dense vegetation, while juveniles more often use trees as resting sites—likely a strategy to avoid predation, including from larger conspecifics (Bennett 1995). The juvenile stage in monitor lizards is characterised by rapid developmental changes and heightened vulnerability, often associated with increased selective pressures (Sumner 2006). During this period, juveniles exhibit more arboreal behaviour than adults (Law et al. 2016), which has implications for movement patterns and habitat use that are not yet well understood.

Previous studies have utilised spool tracking techniques to investigate the movement and activity patterns of monitor lizards, such as *Varanus olivaceus* (Bennett 2014) and *V. bitatawa* (Law et al. 2016). However, to date, no such studies have been conducted in Indonesia despite its high diversity of *Varanus* species. To address this gap, we carried out a controlled experiment using spool tracking to monitor the movement of juvenile water monitor lizards (*V. salvator*) in captivity. The objectives of this study were: (1) to identify the most effective and least intrusive spool attachment position, and (2) to evaluate the behavioural responses of juvenile lizards to spool tracking within a controlled environment.

The study assessing the effectiveness of spool tracking device attachment in monitor lizards was conducted in a dome-shaped enclosure located at the Dramaga Campus of Institut Pertanian Bogor, which functioned as a controlled habitat. The experiment took place over a one-week period, from January 22 to 28, 2020. The dome, situated within the Rectorate Park, measured 11.5 meters in diameter and 7.2 meters in height, with a total surface area of 415.26 m^2. It was constructed from a series of semicircular iron frames covered with fine, perforated wire mesh and enclosed by a circular wall at the base (Figure 1a). The floor was cemented, with an opening located on the western side of the structure (Figure 1b).

For the purposes of the study, the enclosure was divided into two different habitat types: open and vegetated areas. The vegetated sections were dominated by understory plant species including *Asystasia gangetica*, *Derris elliptica*, *Clidemia hirta*, and *Rhoe discolor*. As there was no natural water source within the dome, water was supplied via an open container placed at the centre of the enclosure during the observation period.

We used yarn bobbin cocoons manufactured by Danfields (Leigh, UK), consisting of two thread types: a brown thread weighing 2.6 g with a length

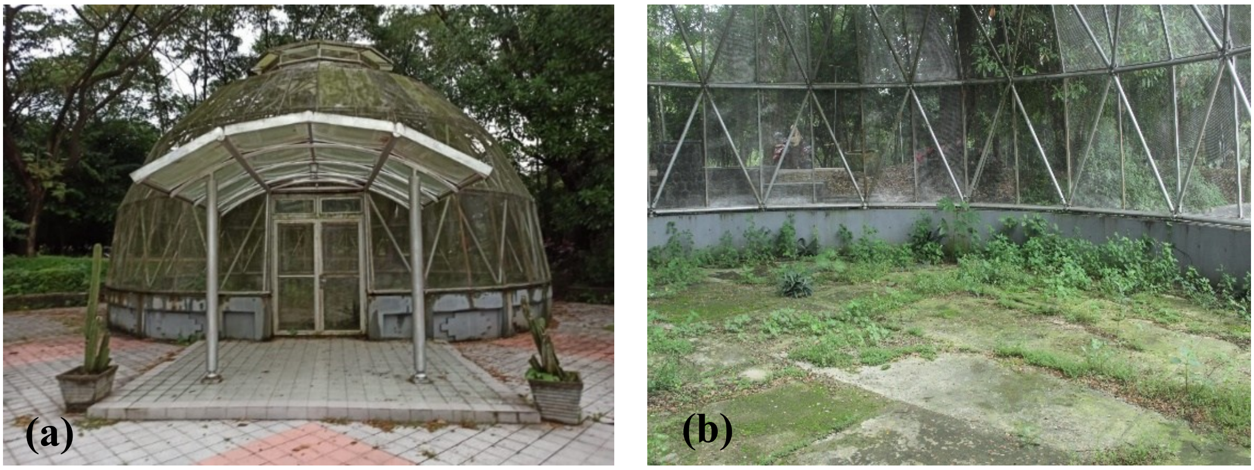

Figure 1. (a) The dome used for experiment and (b) vegetation inside dome.

of 70 m and a white thread weighing 2.2 g with a length of 120 m. The use of two types of threads was necessary to ensure an adequate length for the experiment. The 70-meter thread was initially insufficient to cover the entire required distance, so a 120-meter thread was added to ensure continuous unraveling during the tracking process. This combination ensured that the tracking device functioned effectively throughout the study. The threads were coiled without a central spool, them to unravel smoothly as the animal moved. Prior to data collection, we measured the snout-vent length (SVL) and body mass of each individual. Three juvenile water monitor lizards were used in this study, each with an approximate SVL of 40 cm and body mass around 100 g (Table 1). The animals were sourced from a local hunting group in Bogor (see Yudha et al. 2022 for details on hunting practices).

Before the experiment began, the lizards were acclimatized in the laboratory for one week. During this period, they were housed individually in 30 × 60 cm plastic containers and fed crickets twice daily - one in the morning and again in the late afternoon, following the feeding protocol described by Byers (1999). Routine care was also maintained throughout the acclimation phase, including daily bathing between 07:00 and 12:00 and basking opportunities provided between 08:00 and 15:00.

Table 1. Spool attachment position in juvenile water monitor lizards (*Varanus salvator*) used in the experiment, snout-vent length (SVL), body mass, thread mass and thread length.

ID	Position of spool	SVL (cm)	Body mass (g)	Thread mass (g)	Thread length (m)
BA1	Back area	29.6	63	2.2	120
BA3	Tail	28.7	60	2.2	120
BA2	Control (no spool)	25.4	56	-	-

The spool tracking device was attached to two juvenile water monitor lizards at different body positions: one on the dorsal surface (back) and the other at the base of the tail (Figure 2). A third individual served as a control was not fitted with any device. The yarn used in this study was coiled internally within the bobbin, allowing it to unravel smoothly during movement. To minimise the risk of entanglement, the bobbin was securely fastened with tape (Figure 3a). The thread —made of soft cotton and typically used for embroidery — was selected for its fine texture and flexibility, reducing the risk of injury to the animals. In the event of an escape, the lightweight material was expected to detach easily and safely. In accordance with Bennett (2000), the weight of the thread was kept below 5 % of the lizard's body mass, not exceeding 3 g in any case.

Figure 2. Juvenile water monitor lizard with tracking device positioned at the base of the tail.

The thread was attached either to the mid-dorsal region or base of the tail, with careful positioning to avoid interference with limb movement (Figure 3b and 3c). The free end of the thread was tied to a fixed point were selected randomly within the enclosure, such as a tree or branch, to facilitate unravelling during movement (Figure 3d and 3e). The animals were released into the dome enclosure, and data collection was conducted over two consecutive days for each treatment. In the first trial, the back-mounted lizard and the control individual were released together, followed by the tail-mounted lizard and the same control in the second trial. Observations were made every three hours between 06:00 to 18:00 with each session lasting 30 minutes. The observation intervals were set every three hours to avoid excessive disturbance to the animals and to ensure that enough thread remained for the tracking process. This timing was chosen based on the fact that the lizards were not highly active throughout the entire day, allowing for meaningful observations without frequent interruptions. During these periods, we recorded behavioural responses and spatial use. Movement distance was estimated by measuring the length of the unraveled thread.

During the experiment, we recorded several parameters: the animals' behavioural responses (measured by the number of movements, inferred from the length of thread unraveled), spatial location within the enclosure, total movement distance for each treatment, and the microhabitat characteristics within the dome. The spool attachment position that did not hinder natural movement was considered the most suitable for potential application in tracking juvenile Komodo dragons in the wild.

Upon completion of data collection, all experimental animals were released IPB University campus, which is part of their natural habitat. This study was conducted under an ethical permit issued by the IPB Animal Ethics Commission (Permit No. 175-2020 IPB).

Animal responses to the spool tracking device and microhabitat use were described qualitatively. To evaluate differences in average movement between treatments, movement data were analyzed using a one-way ANOVA. Movements of less than 0.05 m were considered negligible, indicating that the animal remained largely stationary.

Results showed a trend of greater daily movement in lizards with the spool attached to the tail compared to those with the device attached on the back. A significant difference in total movement distance was found between treatments ($F_{10,3}$ = 19.44; P = 0.04) (Table 2). Tail-mounted individuals displayed notable activity, including climbing vegetation up to 2.5 meters in height and attempting to escape via the wire enclosure. All individuals predominantly moved along the perimeter of the dome, with limited use of the central area.

Table 2. Daily movement distances of water monitor lizards over two days, based on spool attachment position.

Variable	Tail	Back side	Mean ± SE
Total movement (m)	167.70	90.30	129.00 ± 38.70
Mean movement per day (m day^{-1})	83.85	45.15	64.50 ± 11.30

Figure 3. Attachment and use of the spool tracking device on juvenile water monitor lizards (*Varanus salvator*): (a) bobbin cocoon thread used in the experiment; (b) spool attached to the mid-dorsal region; (c) spool attached to the base of the tail; (d) free end of the thread secured to a fixed point (tree) to enable unraveling; (e) movement path of the lizard indicated by the trailing thread.

Table 3 summarizes the average activity frequencies of juvenile water monitor lizards under different treatments, recorded at three-hour intervals from 06:00 to 18:00 over two days. Lizards with the spool device mounted on the tail exhibited a higher activity frequency (mean = 13.5, SE = 1.50) compared to those with the device attached to the back (mean = 10.5, SE = 1.32), suggesting that tail-mounted devices may interfere less with natural movement. Control groups without any device attachment (Control-1 and Control-2) recorded the highest activity frequencies, with means of 12.0 (SE = 1.41) and 14.5 (SE = 1.55), respectively. This pattern suggests a slight reduction in activity due to the presence of the spool device, regardless of position, although tail-mounted devices appear to have a lesser impact. Overall, the mean activity frequency across all treatments was 12.81 (SE =

0.74), reinforcing that while tracking devices may affect activity to some degree, proper placement—particularly at the tail—can help maintain behavior levels closer to those of unencumbered individuals.

Table 3. Average movement of juvenile water monitor lizards under different treatments, based on 3-hour interval observations from 06:00 to 18:00 over two days.

Spool location	Frequency of activity	Mean	Std. Eror
Dorsal region	20	10.5	1.32
Control-1	23	12.0	1.41
Tail	26	13.5	1.50
Control-2	28	14.5	1.55
Total	97	12.81	0.74

Most of the experimental animals (76 %) were more active in vegetated areas than in open spaces (24 %). Water monitor lizards ventured into open areas primarily to bask in the sun and to soak in the water provided there. However, the majority of other activities—such as exploration and resting—occurred in vegetated zones, particularly under shaded areas or near small holes.

The results of this study demonstrated that the position of the spool tracking device significantly influences the movement behaviour and overall well-being of juvenile water monitor lizards (*Varanus salvator*). Lizards fitted with tail-mounted spools exhibited greater daily movement distances compared to those with back-mounted devices, with the difference being statistically significant. This suggests that the tail-mounted configurations better in supporting natural locomotion and exploratory behaviour. The enhanced mobility observed in these individuals may be due to reduced interference with limb function and balance—both of which are essential for a semi-arboreal species like *V. salvator*.

Importantly, individuals with the tail-mounted spool device retained the ability to climb vertical structures up to 2.5 meters and engaged in complex behaviours, such as escape attempts, indicating that their physical capabilities were not notably restricted. This contrasts with the back-mounted configuration, which in one case led to thread entanglement and temporary immobilisation. Although such entanglement was not fatal in this study, the incident underscores the potential risk associated with improper device positioning. Similar findings were reported by Susanto (2011), who noted fatal consequences in smaller amphibians due to thread entanglement, particularly when using coarser thread materials. Additionally, Gourevitch and Downie (2018) evaluated tree frog tracking methods and highlighted similar concerns regarding entanglement risks, particularly when using poorly secured or incorrectly positioned devices. These studies emphasised the importance of careful device placement to minimise harm to the animals. The use of finer, smoother cotton thread in our study likely mitigated some of these risks, but it does not eliminate the potential for adverse outcomes when the device is mounted dorsally.

Behavioural observations further supported the preference for tail mounting spool devices. Although all individuals remained active during the daylight hours, consistent with the species' diurnal activity patterns (Byers 1999), lizards in the tail-mounted group showed slightly higher activity frequency. These individuals also explored vertical structures and peripheral areas more extensively, suggesting that the tail-mounted configuration is less disruptive to natural behaviours. Furthermore, the preference for vegetated zones over open spaces observed in most individuals aligns with previous ecological findings (Pah 2003), indicating that the experimental conditions closely approximated the species' natural habitat preferences.

Initial signs of discomfort—such as tail-wagging and hind limb scratching were observed in both treatment groups but diminished rapidly, indicating a capacity for habituation. Nonetheless, device design and placement remain critical. Ensuring at least a 3 cm clearance from the hind limbs appears to be a simple yet effective modification to prevent interference with movement.

In conclusion, the tail-mounted spool configuration offers a more reliable and animal-welfare-conscious method for tracking juvenile water monitor lizards. It allows for natural movement, reduces the risk of entanglement, and provides robust movement data. Future studies aiming to monitor free-ranging individuals in natural habitats should consider adopting this attachment strategy to minimize stress and maximize data quality.

AUTHORS CONTRIBUTION

F.E.S collected and analysed the data and wrote the manuscript in Bahasa Indonesia. M.D.K designed the research, supervised all the process and wrote the translation of manuscript in English. Y.A.M supervised all the process.

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CONFLICT OF INTEREST

No conflict of interest regarding the research or the research funding.

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