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A SIMPLE METHOD OF ATTACHING GPS TRACKING DEVICES TO FREE-RANGING LACE MONITORS (*VARANUS VARIUS*)

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Abstract.—**Effective and reliable methods of attachment for very high frequency (VHF) transmitters to animals are essential for radio-telemetric studies. However, attachment difficulties escalate when longer term studies requiring larger global positioning system (GPS) loggers and additional battery life are required, resulting in the use of larger, more cumbersome units. Lace Monitors (*Varanus various*) of Australia inhabit rugged terrain in the wild, and accurate portrayal of home range and temporal patterns of movement requires a remote data collection process. We developed a robust system of attaching GPS loggers to Lace Monitors, while allowing them to attain a full range of movement, level of activity, and foraging methods. We designed a denim pouch to house a large GPS logger with radio-transmitter, and this unit was then glued to the back of adult Lace Monitors. Fifteen males fitted with denim pouches containing GPS loggers were successfully tracked for 6–65 weeks to study home range and habitat utilization. None of the denim pouches were prematurely dislodged from the animals during the study and pouch design did not appear to affect the natural behavior of the animals. This paper provides a detailed description of the pouch design and the efficacy of its attachment.**

Key Words.—home range, GPS, Lace Monitor, radio telemetry, *Varanus varius*

INTRODUCTION

The Lace Monitor (*Varanus varius*) is one of the largest terrestrial predators in eastern Australia growing to over 10 kg and 2 m in length (Cogger 2000). While the home ranges of this and other species of monitor lizards have been studied (Green et al. 1991; Guarino 2002; Ciofi et al. 2007), little time has been dedicated to studying the reasons for their patterns of movement and how this is related to broader interactions within and between other carnivores in their habitat. In addition to increasing understanding of movement patterns and home range of Lace Monitors, this study aimed to investigate aspects of niche overlap across the carnivore communities within three discrete sites throughout the Greater Blue Mountains World Heritage Area (approximately 60 km west of Sydney) in New South Wales, Australia, in an attempt to determine if exotic carnivores are in competition for common resources with sympatric native predators.

Studies on habitat use to date with Lace Monitors generally have been inconclusive and centred around seasonal patterns of movement, albeit with VHF technology, and no research has attempted to analyze relationships between populations in different habitat types or niche overlap with other predators. One previous study (Guarino 2002) used VHF devices to track a small number of animals over part of the year resulting in some basic home range and diurnal movement information for the species. GPS technology has since advanced, with smaller GPS units now making the precise tracking of small weight range animals possible.

GPS technology has not been used previously with any Australian varanid species and can provide new information on a variety of biological parameters. This paper describes the methods employed to capture these animals for longitudinal studies to establish home range size and seasonal movements. Such information will not only increase our understanding of the Lace Monitor as a species, but will also add to our potential to understand how these animals interact and co-exist with a range of native and introduced carnivores.

MATERIALS AND METHODS

Between March 2008 and April 2009, we captured 15 free-ranging adult male Lace Monitors and we fitted them with custom-made GPS tracker units (Sirtrack Scientific and Industrial Research, Havelock North, New Zealand). Captured animals had an average mass of 6.8 kg (± 0.6 kg) and had an average snout-vent length (SVL) and total length of 74 cm (± 7 cm) and 170 cm (± 14 cm), respectively. We programmed each tracker unit to log the position of the animal hourly between 0600 and 1800 each day, providing precise information about the timing and distance of animal movement. Single-stage VHF transmitters within the 150–151 MHz band are integral to each unit to allow tracking of animals during the data collection phase of the study and recovery of each unit when dislodged from the animal. Each tracking unit weighed approximately 240 g (accounting for less than 4% of animal body mass on average) and had dimensions of 110 x 50 x 20 mm (length x width x height).

***Capture and restraint techniques*.—**We captured animals using cage traps (Tru-Catch Traps, BelleFourche, South Dakota, USA, Model 48F large dog/coyote) approximately 120 x 50 x 65 cm (length x

FIGURE 1. Lace Monitor (*Varanus varius*) in chaff bag showing placement of the denim pouch on the dorsal surface of the animal. (Photographed by Michael Duncan).

FIGURE 2. Lace Monitor (*Varanus varius*) being released on a large tree at the site of capture. (Photographed by Sue Cusbert).

width x height) in size, which we baited with rabbit, hare, or fox carrion. We suspended the baits with nylon rope from the roof of each trap over a self-releasing weight-dependent treadle positioned at the far end of each trap, away from the entrance to the trap. Once lured into the trap in search of the bait, the animal would stand on the treadle, triggering the trap door. Following capture, we photographed each animal and we recorded identifying features and colorations. We then manually restrained animals and carefully removed them from traps before placing them into a chaff bag (Fig. 1). We weighed lizards with a spring balance. The bag was then placed on the ground and physical restraint was applied in front of the forelegs and at the base of the tail of the monitor to allow access to the dorsal surface of the back of each animal. We carefully made an incision approximately the length of the torso of the animal in the bag to expose the back of the animal immediately behind the forelegs so that we could affix the data logger.

***Attaching GPS data loggers*.—**We made double-stitched denim pouches large enough to fully enclose a GPS tracking device (Fig. 1). Each pouch consisted of a rectangle of denim approximately 100 x 200 mm. The edges were 'overlocked' with heavy cotton to minimize fraying during extended periods of deployment. This base provided a surface area of approximately 200 cm^2 of adhesion to the dorsal midline of each monitor. Double-stitched to this base rectangle was a smaller rectangle of denim allowing the GPS loggers to be inserted snugly. We used Velcro tabs to seal the opening, and a gap between the Velcro allowed the VHF antenna to protrude distally.

Attaching the GPS loggers was undertaken by two people, as one person was required to restrain the animal at all times. We smeared a layer of contact cement (Selley's Gel Grip®, Selley's Pty Ltd., Padstow NSW, Australia) on the back of each animal and this was allowed to partially dry until 'tacky' to the touch. At the same time, we smeared a layer of contact cement on to the back of the denim pouch containing the GPS data logger, which was also allowed to partially dry. After approximately 5 min (temperature dependant) when the contact cement on both surfaces became sticky, we placed the denim pouch on the back of the animal and we manually held in place for a further 10 min (approximately) until the pouch had clearly adhered to the skin of the animal (Fig. 1). We took care to ensure that the edges of the pouch were well fixed to the skin, and in some cases, we smeared additional Gel Grip® under the edges of the denim pouch. Attaching the pouches took approximately 20 min per monitor, with none being held for more than 45 min. We then carefully removed the animal from the chaff bag and released it on the nearest large tree at the site of capture (Fig. 2). We radio-tracked and observed all monitors the day after trapping and two to three times seasonally over the study period. The unit was sloughed off the next time the animal shed its skin.

RESULTS

No animals were injured by the trapping process or during manual restraint. The monitor's skin did not appear to be irritated by the Gel Grip, and when attached correctly, the pouches did not dislodge until the animal shed its skin. One pouch that was attached during moderate drizzly rain at sunset, followed by heavy overnight rain, did not adhere to the monitor and was found during routine tracking the following morning at the base of the tree where the animal was released. Another pouch, also attached at sunset in moderate rain, separated from the monitor 44 days after attachment. The remainder of the pouches separated cleanly from the monitors when they shed their skin (Fig. 3). An additional three animals were trapped but not fitted with the pouches as they had commenced shedding.

The denim on the upper surfaces of the pouches was slightly torn in some cases at the time of recovery. On

FIGURE 3. Pouches were recovered when Lace Monitors (*Varanus varius*) shed their skin. (Photographed by Michael Duncan)

two occasions, constant abrasion against cliff-faces and rocks caused the upper surface of the denim pouch to tear to the extent that the GPS loggers separated from the pouches. These animals were re-captured and this problem was remedied by coating the GPS loggers in Gel Grip when inserting them in the pouches.

We recaptured four of the monitors, either accidentally in the process of attempting to cage-trap new animals, or they were captured by hand as they were observed at the end of shedding and the pouch was nearly separated from the animal. Two of these animals had increased in body mass by approximately 10%, one was the same mass as at the time of capture, and the other animal was 18% lighter than the time of capture. It should be noted that the majority of animals often consumed large, but unknown, quantities of the bait when cage trapped, so their body mass may be misleading.

Many of the monitors tracked as part of this study showed inconsistencies in shedding patterns, although four animals appeared to undergo shedding soon after emerging from hibernation. At this point in the study, none of the pouches were shed in inaccessible locations and every GPS logger has been recovered, apart from three, which were still fitted to animals as part of a longer term study.

DISCUSSION

The method described was highly successful for Lace Monitors, and has application to a range of other lizard species, both smaller and larger. The pouches appeared to have minimal impact on the mobility and foraging ability of the monitors. During the study, we radio-tracked and found monitors in various locations, from open cliff-faces, down Wombat (*Vombatus ursinus*) burrows, in hollow logs, across rivers, and in trees up to 6 m above the ground. Placement of the pouches on the dorsal surface of the animal deviated from previous methods with this and other species. While this was primarily done to increase the number of GPS fixes, the slim-line design and absence of straps and webbing appeared to leave the monitors with no noticeable impacts on mobility or flexibility. Other studies with monitors (Ciofi et al. 2007; Green and King 1978) and other lizard species (Warner et al. 2006; Ussher 1999; Richmond 1998) have used harness systems, either around the front or rear legs of the animal, to attach radio-transmitters. Several of these studies reported problems of entanglement, impacted movement and animal injury, and the necessity to recapture the animal to remove the unit. These problems were avoided in the current study using the pouches described. We captured and released several animals without attaching a data logger because they were in the middle of shedding at the time of capture. We considered it unlikely that the Gel Grip would adhere consistently to these animals so they were released from the trap without being touched.

Other studies have used similar methods for attaching transmitters to monitors (Guarino 2002; Green et al. 1991), but the location of attachment was laterally at the base of the tail. These studies did not employ GPS loggers, and hence, the units were considerably smaller than the GPS loggers employed in this study. Despite the fact that our GPS loggers were larger than VHF tracking devices, they have advantages in relation to data acquisition, the precision of the data collected, and time expenditure of the investigators. With the ability to choose the timing and frequency of logging animal position, GPS technology is far more accurate in wildlife research investigating animal movements and home ranges than VHF systems. Whether GPS or VHF units are being deployed, the method of attachment to animals is critical to the success of the study. The method described in this paper has demonstrated that relatively large GPS units can be easily and effectively attached to lace monitors, providing all the benefits of precision collection of data without any apparent impacts on animal movement.

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