Homing: a case-study on the spatial memory of the Asian water monitor lizard *Varanus salvator* in the Kinabatangan floodplain

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Translocation may be used to improve the biological health of animal populations (Wolf et al., 1996) or to mitigate the impact of human-wildlife conflicts (Fisher & Lindenmayer, 2000). However, wildlife species may respond differently to translocations; they can show a tendency to either travel long distances in an attempt to return to their original location (homing), or to exhibit larger home ranges compared to resident individuals (Bradley, 2005; Wolf, et al., 2009). Homing behaviour is negatively correlated with translocation distance (Bowman et al., 2002; Villaseñor et al., 2013), and it is associated with several factors such as the identification of landscape landmarks and resource availability in the original home range (Powell and Mitchel, 2012). Thus, understanding the spatial memory and navigation skills of an organism can be fundamental to predict the success of management actions, such as translocations. This report describes the response of an Asian water monitor (*Varanus salvator*) translocated within the Kinabatangan floodplain in Sabah (Malaysian Borneo) and its return journey to its home territory.

In February 2018, a message was received that a monitor lizard, GPS-tagged as part of a long-term telemetry study, had been feeding on poultry in an oil palm plantation estate (Hillco, Felda Global Ventures Sdn. Bhd.; N5º 25’02” N, E118º 01’46” E). The 17 kg individual (presumably male) was subsequently translocated to a forested area (Lot 6 of the Lower Kinabatangan Wildlife Sanctuary; 5º 24’05” N, 118º 04’27” E), 5.27 km away from its original home range, which had been previously estimated using 2472 locations over 299 tracking days with a fix success rate of 75% (Guerrero-Sanchez et al., unpublished data). A new GPS tracker (Advanced Telemetry Systems Inc., North Isanti, MN, USA) was deployed in order to monitor its adaptations to the new environment (Fig. 1).

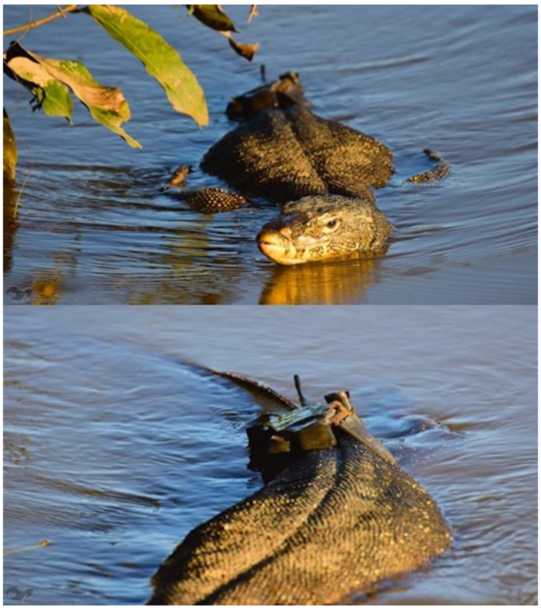

Figure 1. The Asian water monitor with GPS tracker navigating the Kinabatangan river, Sabah, Malaysian Borneo

The new tracker was set to record one GPS location every 90 minutes during daytime; night time was not recorded as water monitors are not active nocturnally. The lizard was tracked for 11 weeks post-translocation, collecting a total of 621 GPS locations. The data show that the lizard took about seven weeks to return to its original home range, but instead of traveling in a straight line or following the river, it travelled through the forest by way of three different plantation "spots" (Fig 2). The last two of those spots were on the same side of the river as the home range, with which there was contiguous plantation habitat, but to reach the home range the monitor instead went through the forest and made further river crossings. This route may have been chosen as unpublished data suggest that forested areas offer more protection to the monitor lizards than oil palm plantations and have prey in equal abundance.

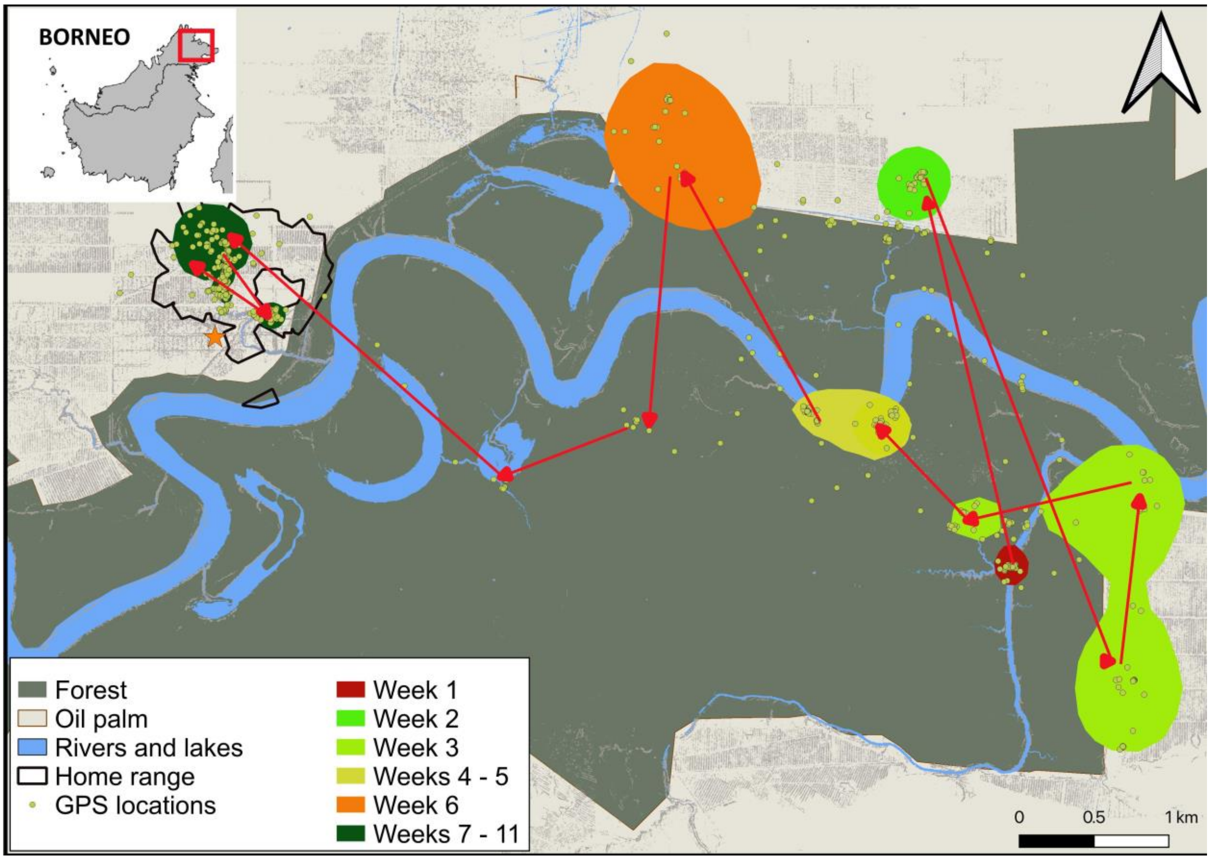

Figure 2. Weekly occupied areas of the translocated monitor lizard in the Kinabatangan floodplain. Polygons represent a 95% home range (kernel density estimate; KDE). Release spot is within the "week 1" polygon. Arrows show the flow of the lizard's movements and the orange star marks the location of the chicken house. KDE was fitted using the package Animove HR for R.

Homing behaviour is not rare in reptiles (Read et al., 2007; Pittman et al., 2014); it has been reported that the saltwater crocodile (*Crocodylus porosus*) can travel up to 400 km back to its original home range after being translocated (Read et al., 2007). Burmese pythons (*Python bivittatus*) possess a well-developed bearing ability that allow translocated individuals to head back home without the need to follow straight lines (Pittman et al., 2014). The natal habitat preference induction theory suggests that when translocated individuals of certain species are looking for a new home they search for habitat attributes similar to those encountered early in life (Davis and Stamps, 2004). Furthermore, the length of time a released individual spends at a release site can be informative about its acceptance or rejection of a new home, while the overall distance travelled during its return can indicate the degree of preference for the special features of its original habitat (Hayward et al., 2007). The time taken by the lizard in this study to return to its original home range, as well as the time spent in certain key areas, (i.e. a different location of an oil palm plantation), suggest that this particular individual was willing to look for a suitable 'new home' with similar features to its original one, but ended up rejecting these areas, possibly due to the presence of other individuals, or unsuitable environmental features (i.e. prey and shelter availability, intense human activity). This report suggests two main drivers influencing the lizard's behaviour: (1) the well-identified habitat of its original home range as a source of predictable food resources and safety, and (2) the discontinuous distribution of these features within the landscape, forcing this individual to avoid these areas and keep moving towards its original home range. We cannot discard the role of the navigational ability and spatial memory that might help the lizard to locate itself within the landscape and find the safest route to his original range (Pittman et al., 2014).

Although it is unclear whether monitors exhibit strictly territorial behaviour (Pascoe et al., 2019), antagonism is likely to occur between males, not only as territorial defence but also as competition for both food and reproductive females (Pascoe et al., 2019). Interestingly, after the return of the lizard to its original home range it was tracked for four more weeks and the data show that it remained within the boundaries of its home range. This behaviour suggests that the lizard not only recognized its home but also that probably no other large individual occupied it during its absence. Hence, what we witnessed could be part of a territorial behaviour, which should be taken into consideration in further studies of human-monitor lizard conflict mitigation.

The water monitor's knowledge of the most relevant elements in its original home range, such as absence of other lizards and the features associated with food and cover, might work as a stimulus for its return to its original home. All these findings suggest that the species may have a well-developed spatial memory, as well as a strong attachment to the well-known features of its home range. These characteristics should be considered in areas where there are human-lizard conflicts and whenever translocated lizards are moved to areas already abundant in monitor lizards. The presence of large monitors in these selected areas can have a counterproductive effect if they result in translocated individuals fleeing and returning to their original homes. In order to get a better understanding of territoriality and habitat preferences of monitor lizards, we recommend carrying out long-term experiments on translocations, using GPS telemetry and considering treatments with varying translocation distance and varying habitat similarities, especially for areas where human-lizard interactions are a burden.

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