The movements and habitat preferences of a Malayan krait (*Bungarus candidus*) in an agrarian landscape

TYLER K. KNIERIM[1], BENJAMIN M. MARSHALL[1], LUCY HAYES[2], SURACHIT WAENGSOTHORN[3], PONGTHEP SUWANWAREE[1] & COLIN T. STRINE[1*]

[1]Suranaree University of Technology, Nakhon Ratchasima, Thailand
[2]Sakaerat Conservation and Snake Education Team, Thailand
[3]Sakaerat Environmental Research Station, Nakhon Ratchasima, Thailand
[*]Corresponding author Email: Colin_Strine@sut.ac.th

ABSTRACT - Little is known about how south-east Asian snakes respond to the conversion of natural areas to human-dominated land uses. We radio-tracked a *Bungarus candidus* (Malayan krait) in an agricultural zone of the Sakaerat Biosphere Reserve in Thailand for 68 days. The snake exhibited nocturnal activity and remained within a 3.23 ha 100% minimum convex polygon (MCP) home range during this period. Using Duncan's Index of Preference, we found the snake preferred less disturbed habitats such as agricultural field margins (0.90), and to a lesser extent, a Eucalyptus plantation (0.75).

INTRODUCTION

South-east Asian landscapes are undergoing rapid anthropogenic change, posing threats to the region's unique biodiversity (Hughes, 2017). To date, most ecological research in the region has been conducted in protected areas or in patches of contiguous habitat (Martin et al., 2012); despite protected areas only representing a small portion of the total global land area (Juffe-Bignoli et al., 2014). To better understand how snakes can persist in human-dominated landscapes, we need a more comprehensive understanding of their space use.

The Malayan krait (*Bungarus candidus*) is distributed across much of south-east Asia and thought to dwell primarily in forests and plantations (Chan-ard et al., 2015; Wogan et al., 2012). Two studies have assessed the spatial ecology and habitat use of *B. candidus* by radio-tracking. One radio-tracked a single individual for 22-days (Mohammadi et al., 2014), the other tracked an individual that only survived 14 days, before being captured and killed in a fish trap within 1 km of our study site (Crane et al., 2016). The objective of our study was to investigate the ecology of a *B. candidus* living within a highly-disturbed landscape, where the risk for human-snake conflict exists. We report our observations on the movements, habitat preference, and shelter site use of an individual *B. candidus* from an agricultural habitat in Thailand.

METHODS

We captured a *B. candidus* at approximately 21:30 h on 8 July 2016, as it crossed a dirt path, dividing a Eucalyptus plantation (*Eucalyptus camaldulensis*) and a cassava field, outside the boundary of the Sakaerat Biosphere Reserve's protected Core Area (14.51º N, 101.95º E; WGS84; Fig. 1A). The individual was male, likely a juvenile, weighing 113.5 g and measuring 77.0 cm snout to vent length (SVL) and 97.6 cm total length. We transported the individual to our field laboratory where we anesthetised and surgically implanted the specimen with a 1.8 g radio transmitter (Holohil Systems model SD-2, Carp, Ontario, Canada). We followed the surgical implantation methods described by Reinert and Cundall (1982), which are believed to not cause physiological or behavioural changes in snakes (Reinert & Cundall, 1982). Later that day at dusk, we released the *B. candidus* at its site of capture.

To receive the transmitter's signal and locate the snake, we used an R410 ATS radio receiver connected to a Telonics RA-23K VHF antenna. On the days that we did track the snake, we tracked it for some hours during daylight and at night-time. In total, we located the snake 21 times during daylight tracks and 13 times at night. During daylight tracking (07:00 h to 19:00 h), we used triangulation to approach the snake, attempting to identify its shelter site while minimising disturbance. We recorded the location of the snake using Universal Transverse Mercator (UTM) WGS 84 projection on a Garmin 64S GPS device. While at each site, we recorded the habitats the snake used, the habitats surrounding the snake's location and attempted to identify the specific shelter site being used. During night-time tracking (19:00 h to 07:00 h), we estimated the snake's position using wide-arcing triangulations at a minimum distance of 10 m from the snake to limit disturbance while it was potentially active. Therefore, we were unable to accurately identify specific shelter sites or cover used at night.

Working in R (R Core Team, 2017) with the software packages adehabitat' (Calenge, 2006), 'rgdal' (Bivand et al., 2017), and using all observed locations, we calculated the home range as 100% and 95% minimum convex polygons (MCP). These were displayed using QGIS (Quantum GIS Development Team, 2017). We opted to use MCPs

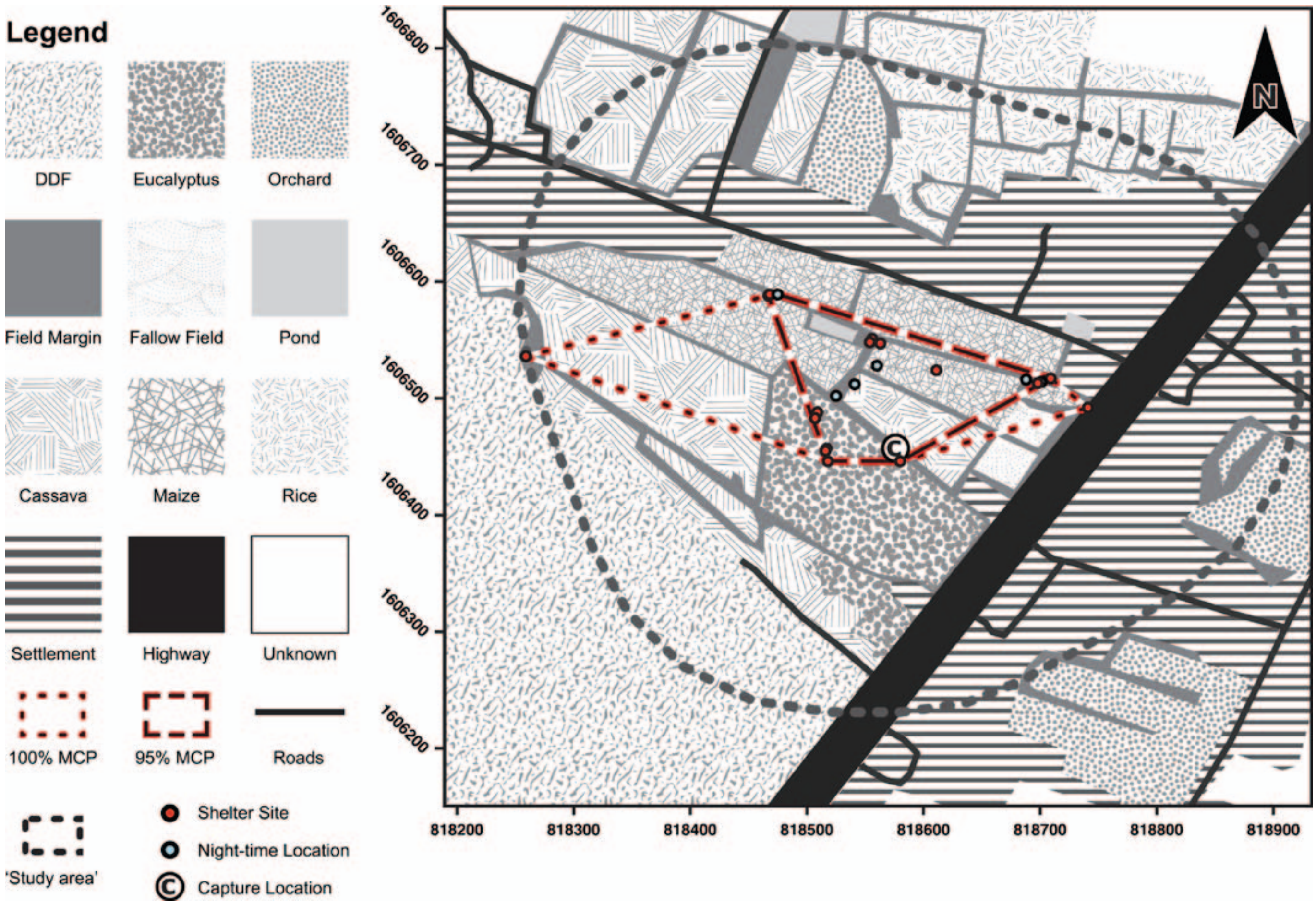

Figure 1. The study area and the 12 habitats located within it. Also displayed are the locations that the *B. candidus* was located as well as the 95% and 100% MCP areas. The map scale corresponds to the 47N UTM region (m), with each grid square equating to 100 m^2.

to measure the home range of our snake instead of more sophisticated estimation methods due to the short tracking duration of our single individual and our limited number of locations. Similar studies on related species have also used MCPs (Mohammadi et al., 2014; Barve et al., 2013; Croak et al., 2013). This allows comparisons with our data.

Habitat preference was based on daytime shelter site locations and estimated using the Duncan's Index which we log normalised between 0-1 (Duncan, 1983). We defined the study area used in our habitat analysis as the region within a 265 m buffer combined with the 95% MCP home range to eliminate bias from areas unused by the *B. candidus*. We derived the width of the buffer from the distance between the nearest edge of the 95% MCP to the furthest outlining observation of the snake. The buffer's width is an estimate of the longest distance the snake could have moved away from its 95% MCP core home range area before returning, i.e. a generous estimation of the area available. We classified 12 habitat types within the study area: roads, highway, human settlement, cassava field, maize field, rice paddy field, fallow field, eucalyptus plantation, mixed fruit orchard, field margin, pond, and dry dipterocarp forest (DDF; Fig. 1). The DDF was within the protected Core Zone, all other habitats were in the reserve's unprotected transitional and buffer zones.

RESULTS

We radio-tracked the *B. candidus* for 68 days (15 July - 21 September 2016) and obtained 34 confirmed locations, until we were unable to obtain a signal due to transmitter failure, or less likely, the individual abruptly leaving the study area. By listening to fluctuations in the signal, we determined that the *B. candidus* was moving during four of the 13 night tracks and one of the 21 day tracks. The sole day time movement occurred at 16:37 h, when the snake appeared to be moving beneath rocks at the location of its previously used shelter site. The ambient temperature was 27.1° C and there was 100% cloud cover, following light rains during the movement observation.

The 100% MCP home range size was 3.23 ha and the 95% was 1.80 ha (Fig. 1). We identified the specific shelter site used by the *B. candidus* on eight of the 19 relocations. The snake sheltered in animal burrows during five tracks, termite mounds during two tracks, and beneath rocks during two tracks. We were unable to identify the specific shelter site during 11 tracks because of dense vegetation.

The Duncan's Index revealed a strong preference for field margins (0.90), the Eucalyptus plantation (0.75), and to a lesser extent, a maize field (0.22). The preference for maize results from a single shelter site location in which the

snake was in a weedy patch of the field, several meters from the field's densely vegetated margin. All other habitat types show no preference and absolute avoidance.
All identifiable shelter sites used by the *B. candidus* during day tracks (animal burrows and termite mounds) were located on field margins or within the Eucalyptus plantation. At one of its shelter sites, the individual sheltered in an animal burrow complex located within 1 m of the four-lane highway at the eastern edge of its 100 % MCP home range. However, we located most shelter sites along a single margin, approximately 3 m wide, and characterised by sparse mature trees, unmanaged herbaceous vegetation, and a dry irrigation ditch running lengthwise through the site. This margin was primarily bordered by maize fields on either side.

We did not observe the *B. candidus* using the DDF, rice fields, fallow fields, orchards, or human settlements (Fig. 1). However, several of the locations within the field margin brought the snake within 10 m of the nearest household. Movements during night tracks showed a similar pattern, suggesting a preference to move along vegetated field margins. The snake was either on or within several meters of a field margin during tracks in which it was moving. The snake made use of a narrow field margin, approximately 1 m in width, to move between the adjoining main field margin and the Eucalyptus plantation.

DISCUSSION

Our juvenile male individual had a smaller 100% MCP home range (3.23 ha) by the end of our 68 day tracking period than the adult male radio-tracked by Mohammadi et al. (2014), (12.30 ha) from their 22 day tracking period. Both snakes were tracked at the apex of the second rainy season between June-September. Our study also confirms nocturnal activity in *B. candidus* which was not reported by either Mohammadi et al. (2014), nor Crane et al. (2016). Additionally, our observations highlight the potential importance of certain landscape features in agricultural landscapes for *B. candidus*. We suspect that both undisturbed raised field margins and irrigation ditches serve as essential shelter sites and movement corridors for *B. candidus*. Choosai et al. (2009) found that dikes and termite mounds hosted higher soil macrofaunal biodiversity than the surrounding fields in north-east Thailand's agricultural rice systems. At our study site, agricultural fields undergo at least two crop rotations per year, subjecting the soil to frequent disturbances. Eucalyptus plantations, which are harvested on a 3-5-year cycle, and field margins, that are left undisturbed long enough to accumulate animal burrows and termite mounds, likely provide a stable source of shelter for *B. candidus*. Discovering when kraits are active and whether preference for field margins and irrigation ditches continues throughout the year for other individuals will aid in identifying areas where *B. candidus* and humans are most likely to encounter each other.

We suggest future research on *B. candidus* in agrarian landscapes to focus on determining activity periods and assessing microhabitat features, such as the availability of shelter sites between margins and adjacent anthropogenic habitats. Identification of specific habitat features will aid the conservation of *B. candidus* in anthropogenic landscapes by providing land managers with explicit features to maintain. Combatting human-snake conflicts in anthropogenic landscapes is critical to the survival of snakes (Whitaker & Shine, 2000) and further research into the movement patterns of this medically important species may provide insight into how this could be achieved. We also suggest incorporating more individuals from varying age classes to investigate whether spatial and activity patterns differ across age classes.

ACKNOWLEDGEMENTS

We thank Suranaree University of Technology for facilitating this project. We would like to sincerely thank the Thailand Institute of Science and Technological Research (TISTR) and The National Research Council of Thailand (NRCT) for funding this project. We are also grateful to the Sakaerat Environmental Research Station for providing ongoing accommodation and logistical support for our herpetological research. Our research methods were carried out with the approval of Suranaree University of Technology's animal use and ethics committee.

REFERENCES

Barve, S., Bhaisare, D. & Giri, A. (2013). A preliminary study on translocation of "rescued" King Cobras (*Ophiophagus hannah*). *Hamadryad* 36: 80-86.

Bivand, R., Keitt, T. & Rowlingson, B. (2017). rgdal: Bindings for the geospatial data abstraction library. R package version 1.2-8. https://CRAN.R-project.org/package=rgdal

Calenge, C. (2006). The package adehabitat for R software: a tool for the analysis of space and habitat use by animals. *Ecological Modelling* 197: 516-519.

Chan-ard, T., Nabhitabhata, J.& Parr, J.W. (2015). *A Field Guide to the Reptiles of Thailand*. Oxford University Press. Pp 251.

Choosai, C., Mathieu, J., Hanboonsong, Y. & Jouquet, P. (2009). Termite mounds and dykes are biodiversity refuges in paddy fields in north-eastern Thailand. *Environmental Conservation* 36: 71-79.

Crane, M., Oliver, K., Silva, I., Aksornneam, A., Artchawakom, T. & Strine, C.T. (2016). A report of a Malayan Krait snake *Bungarus candidus* mortality as by-catch in a local fish trap from Nakhon Ratchasima, Thailand. *Tropical Conservation Science* 9: 313-320.

Croak, B.M., Crowther, M.S., Webb, J.K. & Shine, R. (2013). Movements and habitat use of an endangered snake, *Hoplocephalus bungaroides* (Elapidae): Implications for conservation. *PloS ONE* 8: e61711.

Duncan, P. (1983). Determinants of the use of habitat by horses in a Mediterranean wetland. *The Journal of Animal Ecology* 52: 93-109.

Google Maps. (2014). Satellite imagery. Retrieved via the OpenLayers QGIS plug-in https://www.google.co.uk/maps/@14.4997124,101.9376444,9589m/data=!3m1!1e3!4m2!17m1!1e1

Hughes, A.C. (2017). Understanding the drivers of Southeast Asian biodiversity loss. *Ecosphere* 8: e01624.

Juffe-Bignoli, D., Burgess, N.D., Bingham, H., Belle, E.M.S., de Lima, M.G., Deguignet, M. et al. (2014). Protected Planet Report, Cambridge, UK.: United Nations Environment Programme World Conservation Monitoring Centre (UNEP-WCMC), 2014 978-92-807-3416-4.

Martin, L.J., Blossey, B., Ellis, E. (2012). Mapping where ecologists work: biases in the global distribution of terrestrial ecological observations. *Frontiers in Ecology and the Environment* 10: 195-201.

Mohammadi, S., Kluever, B.M., Tamashiro, T., Amano, Y., Hill III, J.G. (2014). Spatial and thermal observations of a Malayan krait (*Bungarus candidus*) from Thailand. *Tropical Natural History* 14: 21-26.

Quantum GIS Development Team. (2017). Quantum GIS Geographic Information System. Avaiable: http://qgis.osgeo.org

R Core Team. (2017). R: A language and environment for statistical computing. Vienna, Austria: R Foundation for Statistical Computing. Available: https://www.r-project.org/

Reinert, H. K. & Cundall, D. (1982). An improved surgical implantation method for radio-tracking snakes. *Copeia 1982*: 702-705.

Quantum GIS Development Team. (2017). Quantum GIS Geographic Information System. Retrieved from http://qgis.osgeo.org

Whitaker, P. B., Shine, R. (2000). Sources of mortality of large elapid snakes in an agricultural landscape. *Journal of Herpetology* 34: 121–128

Wogan, G., Vogel, G., Grismer, L., Chan-Ard, T. & Nguyen, T.Q. (2012). *Bungarus candidus*. The IUCN Red List of Threatened Species 2012: e.T192238A2059709. Avaiable: http://dx.doi.org/10.2305/IUCN.UK.2012-1.RLTS.T192238A2059709.en. Downloaded on 29 November 2017.

Accepted: 14 February 2018