Tropical Natural History 14(1): 21-26, April 2014

Short Note

Spatial and Thermal Observations of a Malayan Krait (*Bungarus candidus*) From Thailand

SHABNAM MOHAMMADI[1*], BRYAN M. KLUEVER[2], TRACY TAMASHIRO[3], YOHSUKE AMANO[4], AND JACQUES G. HILL III[5]

[1]*Department of Biology, Utah State University, Logan, Utah 84321, USA*
[2]*Department of Wildland Resources, Utah State University, Logan, Utah 84321, USA*
[3]*College of Veterinary Science, Michigan State University, East Lansing, Michigan 48824, USA*
[4] *United Nations University, Institute of Advanced Studies, Yokohama, Kanagawa, 220-8502, JAPAN*
[5] *Division of Reptiles and Amphibians, Department of Zoology, Field Museum of Natural History, Chicago, Illinois 60605, USA*
* Corresponding Author: Shabnam Mohammadi (shab.mohammadi@gmail.com)
Received: 13 October 2013; Accepted: 27 January 2014

The Malayan Krait (*Bungarus candidus*) is a terrestrial Southeast Asian, elapid snake with a range that includes Indonesia, Cambodia, Malaysia, Singapore, Thailand, and Vietnam[1, 2]. This nocturnal species occurs in lowland and hilly regions up to 1200 m[1], and inhabits a wide variety of habitats, including tropical wet and dry forests, tropical montane forests, mangroves, scrublands, plantations, cultivated areas, and the vicinity of villages[1]. Though general species descriptions occur via field guides[1,2], little is known about the ecology of this elusive species.

Data on snake spatial ecology have engendered a better understanding of habitat selection[3,4,5], energetics[6,7] and population ecology[8], which in turn have implications for the conservation and management of various species[8,9,10]. Space use also has important implications in determining and predicting thermoregulatory behaviors of ectotherms, which must actively seek preferred thermal environments to optimize physiological and ecological functions[11,12]. In places where environmental temperatures vary widely, such as in temperate zones, thermoregulation is required for survival and has a substantial influence on life-history traits[13,14]. Many snakes, however, are found in tropical environments where temperatures are relatively stable and warm and thermoregulation plays a subtler yet still important role[15]. Preliminary observations on space use and thermoregulation in an individual of a poorly studied species, like the Malayan Krait, have merit in that they provide a “first look” at certain aspects of the species’ ecology and may help guide future research endeavors. Here we present observations on behavior, movements, habitat use, and body temperature variations of a Malayan Krait that was captured and studied for a short period of time at Sakaerat Environmental Research Station (SERS) in northeast Thailand.

We captured an individual Malayan Krait, which was crossing a road in SERS at 8:18 AM on June 20th, 2007, and transported to a laboratory at the SERS headquarters for processing (Fig. 1). The individual was an adult male weighing 138.1 g and measuring 87.4 cm in snout vent length (SVL) and 98.3 cm in total length (TL).

The snake was immobilized using a restraining tube and anesthetized with 0.3 cc

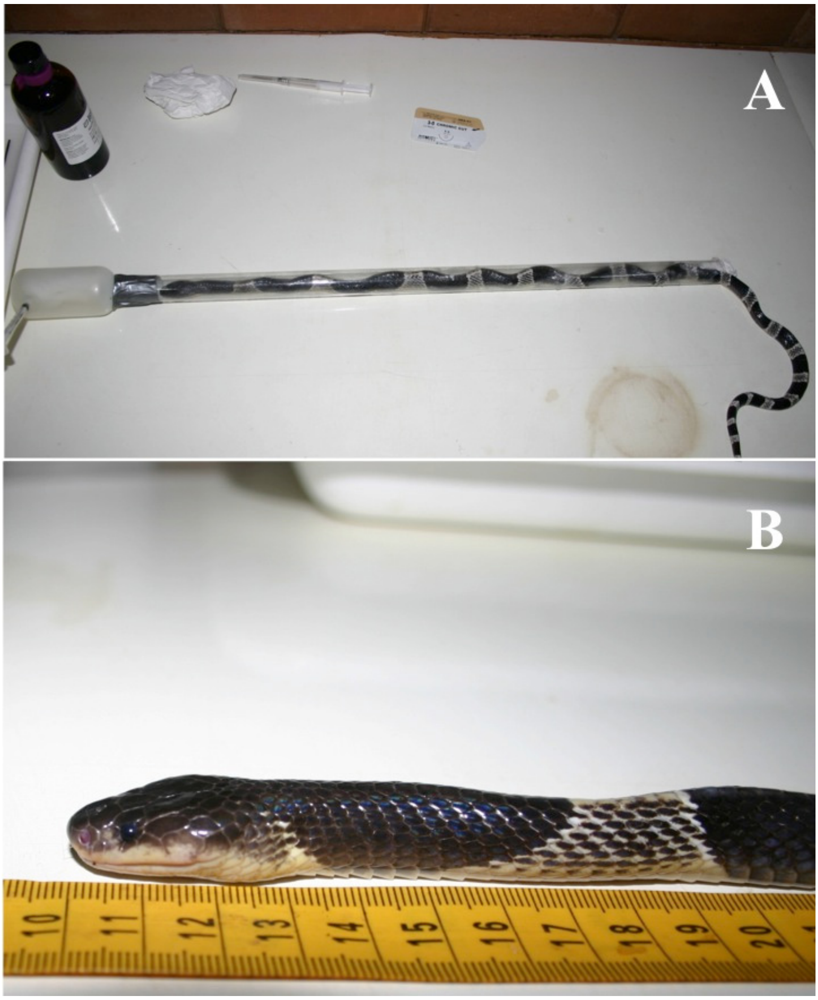

FIGURE 1. The study individual on the night of capture, (A) being anesthetized in the restraining tube with the isoflurane administration chamber attached at the end. (B) Body measurements and scale counts were taken once individual was fully anesthetized.

isoflurane (Fig. 1). We surgically implanted a 2.64 g, temperature sensitive radio transmitter (Holohil Systems model SB-2T, 20 x 10 mm, with a Silastic-coated 180 mm antenna, Carp, Ontario, Canada) into the snake's peritoneal cavity[16]. The snake was held in captivity for a 48-hour recovery period then released at the point of capture. The transmitter signals were in the 173-174 mHz range.

Before implantation, we calibrated the temperature sensitive radio transmitter using a water bath ranging from 5 to 40 °C at approximately 5° increments. This range extended beyond the expected range of environmental temperatures that would be encountered by the snake in nature. An Avionics pulse interval timer (Advanced Telemetry Systems, Minnesota) was used to determine the interval between each pulse produced by the radio transmitter (interpulse interval or IPI). A regression was generated in JMP, Version 10.0 (SAS Institute Inc., Cary, NC, 1989-2007), to create a calibration curve, which explained the relationship between IPI and snake body temperature (T_b). The calibration curve explained greater than 95% of the variance in temperatures measured by the radio transmitter. The calibration curve was later used to predict T_b from IPIs obtained in the field.

After release, we located the snake once every day for 22 days, with the exception of three single-day intervals (see Table 1), typically between 8:00 AM and 5 PM., using a Wildlife Materials TRX 1000S Radio Receiver (Murphysboro, Illinois, U.S.A.) with a Yagi three-element directional antenna. We determined the location of the animal on the UTM grid system with a Garmin GPS II Plus GPS unit (Garmin Corporation, Olathe, Kansas, USA). On the 23rd day of radio telemetry, the snake moved out of our detectable range and we were not able to locate it again.

At each snake location we recorded the snake's behavior as active (i.e., moving) or sedentary. If the snake was sedentary we noted if the snake was sheltered. We considered a snake "sheltered" if it was inside of a structure such as a hollow log, rock crevice, or under dense brush pile. We determined IPI each time we relocated the snake. Maximum and minimum environmental temperatures (T_e) were acquired from a weather station located in the dipterocarp forest where the snake was tracked throughout the 22-day period because we were not able to take *in-situ* ambient temperatures at each snake location.

We calculated mean daily distance moved as the straight-line distance between the GPS coordinates of successive telemetry locations divided by the number of days elapsed using the Hawth's Tools extension in ArcGIS 9.2 (ESRI, Redlands, CA, USA). Frequency of movement was calculated as the proportion of snake relocations more than 10 m from the previous location. We also calculated the mean resting duration as the number of successive days without moving more than 10 m.

A minimum convex polygon (MCP) home range for the 22 day tracking period was calculated with a 100% a minimum convex polygon using the Hawth extension in ArcGIS 9.3 (ESRI, Redlands, CA, USA). MCPs are simple to conceptualize, do not require the sample sizes necessary to meet assumptions of underlying statistical distribution[17], and do not require the estimation of parameters (e.g., smoothing factor) that influence home range size[18]. We felt it was inappropriate to consider the MCP for the study animal as a complete home range because previous research has found that snakes need to be tracked for nearly two months before they reached an asymptote in home range area[7].

We determined macro-habitat use for the study animal by overlaying the snake MCP home range with a 2008 SERS raster land cover map[19]. We used the GSME extension in ArcGIS 10.1 to determine the amount of land cover within the snake MCP home range, as well as the land cover type that overlapped each snake location. We tested if the proportion of spatial locations within each land cover type (i.e., macro-habitat selection) was equal to the proportions of available land cover types (i.e., macro-habitat availability) using a Chi-square goodness of fit test (JMP 9.0, SAS Institute, Cary, NC, USA) at a significance level of $P < 0.05$.

TABLE 1. Habitat use and body temperature data presented with date and time, and environmental climate. Periods represent blank data points. When snake was underground but no access point (e. g., a hole) was visible, shelter type was marked 'underground'.

Date	Time	Shelter Type	Body Temp. (°C)	Avg. Max. Evironmental Temp. (°C)	Avg. Min. Evironmental Temp. (°C)
6/30/07	16:50	underground	26.8	33.1	24.6
7/1/07	16:50	no shelter, moving	27.3	31.6	24.1
7/3/07	16:10	hole in tree	.	32.7	24.6
7/5/07	12:30	termite mound	26.2	33.6	24.7
7/7/07	14:31	termite mound	26.6	31.7	23.5
7/8/07	14:55	termite mound	26.7	33.6	24.1
7/9/07	9:40	termite mound	.	32.7	23.6
7/10/07	17:20	termite mound	26.3	32.2	24.5
7/11/07	15:05	termite mound	26.3	33.7	24.9
7/12/07	10:25	termite mound	26.7	33.8	25.1
7/13/07	13:15	termite mound	27.1	33.4	25.3
7/14/07	10:02	termite mound	27.3	33.7	24.2
7/15/07	8:35	termite mound	27.1	33.8	24.1
7/16/07	9:59	termite mound	27.4	34.8	24.7
7/17/07	9:55	termite mound	26.2	33.4	25.2
7/18/07	12:28	termite mount	26.0	32.9	26.8
7/19/07	10:55	hole in ground under a rock	26.3	33.0	26.4
7/20/07	10:08	hole in ground under a rock	26.9	33.7	25.4
7/21/07	10:17	underground	26.8	33.3	25.2

The krait was located 19 times. The snake was sedentary during 95% (18 of 19) of encounters, and was observed moving on one occasion. The snake was sheltered during all sedentary encounters and utilized various types of shelters (Table 1), but was located in a single termite mound during 72% (13 of 18) of the sedentary encounters. The krait moved during 69% (n = 11) of relocations. The average daily distance traveled between movements was 123.1 m (SD = 145.0) and ranged from 10.5 to 501 m. The snake was found to be resting during 31% (n = 5) of relocations. The MCP home range size for the krait was 12.3 ha and occurred in two land cover types; dry evergreen forest and deciduous forest. Dry evergreen forest made up 24% of the snake MCP home range, while deciduous forest encompassed 76%. The number of snake locations that occurred in dry evergreen forest and deciduous forest were ten (59%) and seven (41%), respectively. We found evidence that macro-habitat use at the home range level was not proportionate to available habitat (chi-square = 10.373, df = 1, P = .00128).

The average sedentary body temperature of the krait during the study period was 26.7 °C (range = 26.0 – 27.4; STDEV = 0.41). The average daily maximum environmental temperature over the 22-day period was 33.2 °C, and the minimum was 24.8 °C. We only recorded one body temperature for the snake while it was active (27.3 °C). Based on the limited data, we cannot make inferences on this species' thermal ecology. However, we believe that these data can be useful for future research endeavors, including studies that pool available data from literature[20].

The krait utilized a termite mound during a majority of observations. Malayan kraits consume other snakes as a main part of their diet[21], and we speculate that the individual might have been hunting for blind snakes (Typhlopidae), which feed on termites[22]. It is also possible that the termite mound simply served as a shelter with a suitable thermal environment. After the 22nd day of radio tracking we were unable to obtain a signal for the snake. Signal loss could have been caused by antennae failure, the animal moving out of our telemetry equipment's range, or the krait being carried off by a predator. In one case, a Malayan Pitviper (*Calloselasma rhodostoma*) that was being radio-tracked on a sister study was carried off by a raptor. The radio was found in a bird scat within a nest one mile from the snake's previous location (J.G. Hill III, pers. comm., December 20th, 2013).

The mean and maximum daily movements that we recorded are greater than those recorded for several snake species[3,7,23], but given our small sample size caution is warranted as to if these rates are representative for Malayan kraits at a population level. Additional tracking efforts are needed in order to determine if biological (e.g., sex, reproductive condition) and environmental factors (e.g., season, prey availability) influence movement patterns for this species. Home range size for snakes is correlated to the number of tracking days[5,23], and our radio tracking effort only encompassed 22 days. As a result, reliable estimates of Malayan krait home ranges (both annual and seasonal) will remain unknown until additional research occurs. However, our findings reveal that Malayan Krait home ranges are likely to be greater than 12.3 ha. The Malayan Krait utilized both dry evergreen and deciduous forest. A majority of the snakes' MCP home range comprised of deciduous forest, but the majority of snake locations occurred in dry evergreen. This observation, coupled with our analysis, suggests that the krait preferred dry evergreen forest. The reason(s) for such a preference may be related to a host of factors (i.e., prey availability, thermal shelter availability, predation risk) and deserve further exploration. Malayan Kraits have the potential for conflict with humans, especially in agricultural and rural areas[24]. The maximum length of the krait MCP home range was 1180 meters. We recommend that problematic snakes be transported at least a distance of 1200 m when translocation is employed as a method to mollify human-Malayan Krait conflicts. Though limited in scope and inference, our findings on behavior, movements, habitat use, and thermoregulation provide initial data for this elusive and poorly understood species.

ACKNOWLEDGEMENTS

This research was conducted with permission of the National Research Council of Thailand, Permit # 09/50, issued to JGH. We thank Taksin Artchawakom and the staff of SERS for their assistance in conducting this research. We also thank Harold Voris (Field Museum of Natural History), Daryl Karns (Hanover College), Kumthorn Thirakupt (Chulalongkorn University), Lawan Chanhome (Queen Saovabha Memorial Institute, Thai Red Cross Society), and Nathawut Thanee (Suranaree University of Technology) for their collaborative support on all of our work in Thailand.

LITERATURE CITED

1. David, P. and Vogel, G. 1996. The Snakes of Sumatra: An annotated checklist and key with natural history notes, Edition Chimaira, Frankfurt, 259pp.
2. Cox, M.J., van Dijk, P.P., Nabhitabhata, J. and Thirakhupt, K. 1998. A Photographic Guide to Snakes and other Reptiles of Peninsular Malaysia, Singapore and Thailand. Ralph Curtis Books, Sanibel Island, 144pp.
3. Lee, H., Lee, J. and Park, D. 2011. Habitat use and movement patterns of the viviparous aquatic snake, *Oocatochus rufodorsatus*, from Northeast Asia. Zool. Sci., 28: 593-599.

4. Miller, G.J., Smith, L.L., Johnson, S.A. and Franz, R. 2012. Home range size and habitat selection in the Florida pine snake (*Pituophis melanoleucus mugitus*). Copeia, 2012: 706-713.
5. Croak, B.M., Crowther, M.S., Webb, J.K. and Shine, R. 2013. Movements and habitat use of an endangered snake, *Hopocephalus bungaroides* (Elapidae): Implications for Conservation. PLOS ONE. 8: 1-10.
6. Shine, R., Sun, L.X., Fitzgerald, M. and Kearney, M. 2003. A radiotelemetric study of movements and thermal biology of insular Chinese pit-vipers (*Gloydius shedaoensis*, Viperidae). Oikos, 100: 342-352.
7. Lelièvre, H., Moreau, C., Blouin-Demers. G., Bonnet, X. and Lordais, O. 2012. Two syntopic colubrid snakes differ in their energetic requirements and their use of space. Herpetologica, 68: 358-364.
8. Hyslop, N.L., Stevenson, D.J., Macey, J.N., Carlile, L.D., Jenkins, C.L., Hostetler, J.A. and Oli, M.K. 2012. Survival and population growth of a long-lived threatened snake species, *Drymarchon couperi* (Eastern Indigo Snake). Popul. Ecol., 54: 145-156.
9. Maritz, B. and Alexander, G.J. 2012. Dwarfs on the move: spatial ecology of the world's smallest viper, *Bitis schneideri*. Copeia, 115-120.
10. Shew, J.J., Greene, B.D. and Durbian, F.E. 2012. Spatial ecology and habitat use of the western foxsnake (*Pantherophis vulpinus*) on Squaw Creek National Wildlife Refuge (Missouri). J. Herpetol., 46: 539-548.
11. Huey, R.B. 1982. Temperature, physiology, and the ecology of reptiles. In Gans, C. and Pough. F.H. (Eds). Biology of the Reptilia. Academic Press, New York, pp. 25-91.
12. Mori, A., Toda, M. and Ota, H. 2002. Winter activity of the Hime-Habu (*Ovophis okinavensis*) in the humid subtropics: Foraging on breeding anurans at low temperatures. In Schuett, G., Hoggren, M., Douglas, M.E., and Greene, H.W. (Eds.). Biology of the Vipers. Eagle Mountain Publishing LC, Eagle Mountain, Utah. pp. 329-344.
13. Bennett, A.F. and Nagy, K.A. 1977. Energy expenditure in free-ranging lizards. Ecology, 58: 697-700.
14. Hertz, P.E., Huey, R.B. and Stevenson, R.D. 1993. Evaluating temperature regulation by field-active ectotherms: the fallacy of the inappropriate question. Am. Nat., 142: 796-818.
15. Anderson, N.L., Hetherington, T.E., Coupe, B., Perry, G., Williams, J.B. and Lehman, J. 2005. Thermoregulation in a nocturnal, tropical, arboreal snake. J. Herpetol., 39: 82-92.
16. Reinert, H.K. and Cundall, D. 1982. An improved surgical implantation method for radio-tracking snakes. Copeia, 1982: 702-705.
17. Powell, R.A. 2000. Animal home ranges and territories and home range estimators. In Boitani, L. and Fuller, T. (Eds.). Research techniques in animal ecology: controversies and consequences. Columbia University Press, New York, pp. 65-100.
18. Row, J.R., Blouin-Demers, G. and Weatherhead, P.J. 2007. Demographic effects of road mortality in BlackRat snakes (*Elaphe obsoleta*). Biol. Conserv., 137: 117-124.
19. Trisurat, Y. 2010. Land use and forested landscape changes at Sakaerat Environmental Research Station in Nakhorn Ratchasima province, Thailand. Ekológia, 29: 99-109.
20. Brattstrom, B.H. 1965. Body temperatures of reptiles. Am. Midl. Nat., 73: 376-422.
21. Kuch, U. and Zug, G.R. 2004. *Bungarus candidus* (Malayan krait). Diet. Herpetol. Rev., 35: 274.
22. Shine, R. and Webb, J.K. 1990. Natural history of Australian typhlopid snakes. J. Herpetol., 24: 357-363.
23. Madsen, T. 1984. Movements, home range size, and habitat use of radio-tracked grass snakes (*Natrix natrix*) in southern Sweden. Copeia, 1984: 707-713.
24. Viravan, C., Looareesuwan, S., Kosakarn, W., Wuthiekanun, V., McCarthy, C.J., Stimson, A.F., Bunnag, D., Harinasuta, T. and Warrell, D.A. 1992. A national hospital-based survey of snakes responsible for bites in Thailand. T. Roy. Soc. Trop. Med. H., 86: 100-106.