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Morphology, Activity Area, and Movement Patterns of the Frugivorous Monitor Lizard *Varanus bitatawa*

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***Abstract*.—The newly described *Varanus bitatawa* is a large, frugivorous, monitor lizard endemic to the northern Sierra Madre mountain range in Luzon, Philippines. This study presents the first description of its ecology from tracking and camera trapping. We captured five adult lizards weighing 1.0–5.1 kg with snout-vent lengths (SVL) from 40–66 cm and total lengths from 100–164 cm. Activity areas were non-overlapping with a mean of 12,400 m^2; males (23,300 m^2) had larger activity areas than females (5,200 m^2). Capture and camera trap records indicate that lizards move most frequently between 1000 and 1500. Movements were characterized by straight line distances between trees with a mean distance travelled between trees of 79 m. Mean daily distance covered was 176 m with larger distances covered by males (228 m vs 142 m for females).**

Key Words.—camera trapping; frugivory; Luzon; Northern Sierra Madre Natural Park; Philippines; spool and line tracking; varanid ecology; Varanidae

Introduction

Frugivorous monitor lizards are only known from the Philippines. This group includes three allopatrically distributed species: *Varanus olivaceus* (originally described in 1845 by John Grey; Auffenberg 1988), *Varanus mabitang* (Gaulke and Curio 2001), and the recently described *Varanus bitatawa* (Welton et al. 2010). We propose the vernacular name Bitatawa for *V. bitatawa*, analogous to the vernacular names Butaan (*V. olivaceus*) and Mabitang (*V. mabitang*) that all originate from local languages. Bitatawa is one of the local names used by Agta hunters for *V. bitatawa* (Welton et al. 2010). Currently known to be restricted to the northern Sierra Madre mountain range, *V. bitatawa* shares its distribution with the sympatrically occurring water monitor lizard *Varanus marmoratus*. The shy and secluded nature of *V. bitatawa* has made conducting research to collect primary data on this new species problematic. There have been no additional publications on the biology and ecology of *V. bitatawa* since its first description in 2010. The only insight to this species to date is from local ecological knowledge gained through extensive interviewing of hunters (Besijn 2012).

Unlike *V. bitatawa*, the morphology and ecology of *V. olivaceus* have been studied relatively well on Luzon and Catanduanes Islands (Auffenberg 1988) and on Polillo Island (Bennett 2000; Bennett and Hampson 2001; Bennett 2014). The largest measured *V. olivaceus* was 188 cm long and had a mass of 8.9 kg (Daniel Bennett, unpubl. data). *Varanus olivaceus* is obligatory frugivorous and feeds on a variety of fruits that it actively picks directly from fruiting trees. Its diet is supplemented with snails and hermit crabs (Bennett and Hampson 2001; Bennett 2014). Activity areas ranged from 2,200–27,100 m^2 in a study of nine adult radio-tagged *V. olivaceus* (Auffenberg 1988). The Mabitang was studied by Gaulke and colleagues (summarized in Gaulke 2010) on Panay Island. The largest *V. mabitang* measured was 175 cm long and weighed 8 kg. *Varanus mabitang* seems even more specialized in a frugivorous diet than *V. olivaceus* with very few carnivore elements and evidence of folivory (Gaulke 2010). Activity areas and home ranges have not yet been reported for *V. mabitang*. The largest measured *V. bitatawa* was 180 cm long and weighed 9 kg (Welton et al. 2010).

Lack of knowledge of *V. bitatawa* will affect its conservation. Our study presents the first description of its ecology based on field research. Our objectives were to collect further baseline morphometric data of the species and determine movement patterns and estimates of activity area. We compare these data with available information on its congeners, *V. olivaceus* and *V. mabitang*.

Materials and Methods

Study site.—The northern Sierra Madre range runs along the eastern part of northern Luzon, Philippines, with peaks reaching a maximum elevation of about 1,850 m. The climate of the area is tropical and is dominated by the northeast (November-February) and southwest (June-October) monsoons with the driest period between February and May. Rainfall is strongly influenced by frequent typhoons and varies from an average of 1,649 mm (Tuguegarao; range 967–2,596 mm in the period 1975–2004) in Cagayan Valley west of the mountain range to an average of 3,534 mm (Casiguran; range 2,016–5,740 mm in 1975–2004) at sea level on the eastern side of the Sierra Madre (Philippine Atmospheric, Geophysical and Astronomical Services Administration 2005). The Sierra Madre has the largest remaining forest cover of the Philippines (Tan 2000). The Lowland Forest is dominated by dipterocarp species but has been disturbed by logging, even inside protected areas (van der Ploeg et al. 2011b). In addition to Lowland Forest, the area has large areas of forest on ultrabasic soils and, in elevations over 800 m, Montane Forest (van Weerd and Udo de Haes 2010).

We collected data in disturbed lowland dipterocarp forest in two locations from June to August 2013: the Northern Sierra Madre Natural Park (NSMNP) in Isabela Province and the Peñablanca Protected Landscape and Seascape (PPLS) in Cagayan Province. We do not report precise locality data here to prevent collection of lizards by pet traders (Auliya et al., In press), following recommendations by Chapman (unpubl. report) and the guidelines of *Herpetological Conservation and Biology* (Instructions For Authors), but locality coordinates have been deposited with the Mabuwaya Foundation, a conservation organization based in Isabela Province, Philippines. The NSMNP is one of the richest protected areas in the Philippines in terms of biodiversity (van Weerd and Udo de Haes 2010), whereas the northern Sierra Madre in Isabela and Cagayan Provinces is emerging as one of the richest areas in terms of amphibian and reptile diversity (Brown et al. 2013).

Capture.—We caught monitor lizards with the assistance of a local hunter. The hunter sought lizards using a hunting dog to locate animals and captured them using a noose attached to a long pole when they sought refuge in a tree. We also set noose traps on the ground adjacent to fruiting trees. A search party consisted of a single hunting dog and three people. We searched forested areas opportunistically between 0900 and 1700. Similar capture methods were used for *V. olivaceus* (Auffenberg 1988; Bennett 2000). We processed all lizards caught and released them at the site of capture within half an hour. We calculated encounter rates (ER) by dividing the number of individuals sighted by the number of hours searched. We compared ER for *V. bitatawa* with ER of the sympatrically occurring *V. marmoratus* and with ER of *V. olivaceus* on Polillo Island (Bennett 2000).

Morphometrics.—To minimize stress and reduce processing time of captured lizards, we choose to only take measurements that were comparable to other varanid studies (Auffenberg 1988; Bennett 2000; Gaulke 2010; Welton et al. 2010; Somma and Koch 2012). We recorded the following morphometric characteristics using tape measurers or calipers to the nearest centimeter or millimeter: snout-vent length (SVL), tail length (combined with SVL for total length [TL]), circumference of head, body at widest point and tail base, head length, width and depth at the largest point, and length of the right forelimb and hind limb. We recorded weights using a spring balance with ± 100 g accuracy. We searched for the presence of ectoparasites and distinguishing features such as old or recent injuries. We identified sex of individuals by eversion of the reproductive organ upon capture. Mature adult males evert a large hemipenis but females often evert a hemiclitoris, which can be difficult to distinguish from the hemipenes of juvenile males (Auffenberg 1988).

Spool and line tracking.—We attached cocoon bobbins of polyester thread (Danfield Ltd., Leigh, England), tied together in alternating colors and wrapped in plastic, with duct tape to the tail beyond the maximum reach of the hindlimbs (Fig. 1). Each spool weighed approximately 5 g, measuring 39 × 15 mm and containing 300 m of thread (Bennett 2000). The devices did not exceed 5% of the individuals total body weight. We followed thread trails each morning between 0800 and 1100 and recorded bearing and distance of the thread. We noted characteristics of trees climbed (species, circumference at breast height [CBH], fruit absent/present). We recorded latitude/longitude coordinates at site of capture, at each tree climbed and at the point where we recovered shed spools. In the absence of studies comparing the impact of a spool and line device on varanid behavior, we assumed that the tag did not alter normal behavior for data analysis. Using the convex polygon method (MacDonald et al. 1980), we plotted the minimum perimeter of movement and estimated the area of activity. Activity area is defined as the area within which the lizard could be found within a defined time period (Thompson et al. 1999). We determined the relationship between SVL with activity area and distance travelled on the ground.

Camera trapping.—We placed two Moultrie Game Spy infrared cameras (model M-80XT; EBSCO Industries, Inc., Calera, Alabama, USA) opposite the last

Figure 1. Photographs showing (A) cocoon bobbins of polyester thread tied together, (B) the attachment of the spools to the tail of a *Varanus bitatawa* and (C) *Varanus bitatawa* at release with a blue tracking line attached to a stem. (Photographed by Stephanie Law).

known tree climbed by a tagged individual. We set cameras to operate continuously for 24 h and to take three photos per second each time the camera was triggered with a 5 s delay between trigger events. A trigger event refers to a series of three pictures taken by the camera within 1 s and capture rate refers to the mean number of trigger events for the duration the camera was left at a particular site.

Results

***Capture and effort*.**—All successful captures were made by local hunters. We did not capture individuals in the ground noose traps. We caught four *V. bitatawa* in the NSMNP and a further two in the PPLS. Accompanying a local hunter and the use of a dog inevitably posed risks to the lizards; one juvenile individual received fatal injuries from the dog upon capture. In each

Table 1. Encounter rate of *Varanus bitatawa*, *V. marmoratus*, and *V. olivaceus* in the Peñablanca Protected Landscape and Seascape (PPLS), Cagayan Province, Luzon; Northern Sierra Madre Natural Park (NSMNP), Isabela Province, Luzon; Polillo Island. Data for *V. olivaceus* from Bennett 2000.

	Encounter Rate (sightings per hour)		
Location	*Varanus bitatawa*	*Varanus marmoratus*	*Varanus olivaceus*
PPLS	0.095	0.476	—
NSMNP	0.127	0.286	—
Polillo Island	—	0.092	0.067

location of the NSMNP and the PPLS, we spent 31.5 h searching. We recorded 13 sightings of monitor lizards in the NSMNP and 24 sightings in the PPLS. Of the PPLS sightings, six could not be identified as either *V. bitatawa* or *V. marmoratus* and have been omitted from calculations of ER. The ER was between 2.3 and five times lower for *V. bitatawa* compared to the sympatrically occurring water monitor, *V. marmoratus* (Table 1).

Morphometrics.—We were able to evert reproductive organs from all individuals we caught and we assigned sex, although we recognize some individuals may have been assigned incorrectly. All animals were in good physical condition with no visible ectoparasites. Auffenberg (1988) suggested that mature *V. olivaceus* would have a SVL > 40 cm, thus data for one smaller male *V. bitatawa* was removed from this study to compare morphometrics of mature individuals. Mean TL was 132 ± SE 11.7 cm (range 99.5–164 cm) and mean mass was 3.12 ± 0.81 kg (range 1.0–5.1 kg). Comparisons of measurements between the three frugivorous monitor lizards endemic to the Philippines show considerable similarity (Table 2). Due to the uncertainty of sex assignment in the field and the lack of reported sex-specific measurements for *V. mabitang*, we did not make comparisons based on sex.

Activity area.—We tracked five of the six lizards caught that had a SVL ≥ 40 cm. The minimum perimeter of the activity area showed very little or no overlap between individuals caught in the same location (Fig. 2). Males were found to have a larger mean activity area (mean = 23,300 ± 8,350 m^2, range 14,900–31,600 m^2, *n* = 2) than females (mean = 5,200 ± 3,667 m^2, range 500–12,400 m^2, *n* = 3). Linear movements between trees meant that a lizard would not use large sections of its minimum convex polygon. Lizards with a larger SVL most often traveled a greater total distance over ground with a larger estimated activity area than smaller lizards (Fig. 3).

Daily movement.—We followed tagged individuals for 4–17 d with a mean of 11.2 d. Mean time spent in a single tree was 3.3 d with a range of 1–8 d. Lizards travelled a mean daily distance of 176.7 ± 52.5 m with males covering greater distances (mean = 227.5 ± 78.5 m, range 149–306 m, *n* = 2) than females (mean = 142.3 ± 75.3 m, range 53–292 m, *n* = 3; Table 3). Escape response, defined here as the mean distance travelled to the first tree following release, was similar to the mean distance travelled between trees in subsequent tracking periods (mean = 81.4 ± 36.8 m and mean = 79.0 ± 27.7 m, respectively) so we assume the capture itself had no impact on travel distances. Following release, lizards remained in a single tree for a mean time of 2.4 d (range 1–6 d). Following release, five of the six lizards climbed large (circumference at breast height: 190–320 cm) Red Lauan trees, *Shorea negrosensis* (Dipterocarpaceae). Mean daily distances moved on the ground (DG) was 516 ± 125.3 m, in trees (DT) was 496 ± 82.8 m, and between trees (BT) was 79 ± 27.7 m for tagged *V. bitatawa*.

Table 2. Mean (± SE) and range of morphology traits of *Varanus bitatawa* (Northern Sierra Madre Natural Park and Peñablanca Protected Land and Seascape; *n* =5), *V. olivaceus* (Polillo Island; *n* = 7), and *V. mabitang* (Panay Island; *n* = 23) in the Philippines. Measurements other than mass are in centimeters. Data for *V. olivaceus* from Daniel Bennett (unpubl. data) and for *V. mabitang* from Gaulke (2010). Abbreviation SVL = snout-vent length. Dashes represent data unreported.

	Varanus bitatawa		*Varanus olivaceus*		*Varanus mabitang*	
Trait	Mean	Range	Mean	Range	Mean	Range
Mass (kg)	3.12 ± 0.81	1.00–5.10	4.90	1.13–8.90	3.06	1.00–8.00
SVL	53.2 ± 5.02	40.0–65.5	58.5	42.2–73.0	54.2	42.0–70.0
Tail length (TaL)	79.0 ± 6.67	59.5–98.0	87.9	64.0–115.0	82.0	63.0–101.0
Ratio: TaL/SVL	1.49	1.38–1.58	1.51	1.44–1.58	1.45	1.36–1.61
Total Length	132 ± 11.7	99.5–164	146	106–188	136	101–175
Tail circumference	17.3 ± 2.10	12.4–23.5	19.6	11.9–24.6	—	—
Body circumference	31.8 ± 3.06	23.0–39.5	35.4	22.5–47.0	—	—
Head width	4.40 ± 0.57	3.3–6.5	5.50	4.0–7.1	—	—

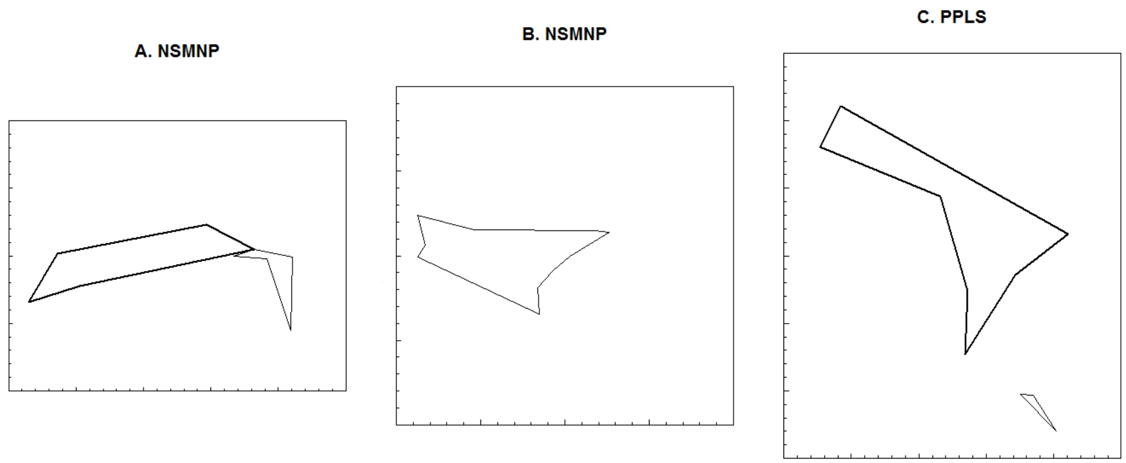

Figure 2. Left (A) and center (B) polygons show the minimum perimeter and resultant activity area of tagged *Varanus bitatawa* caught and tracked in the Northern Sierra Madre Natural Park (NSMNP). Right (C) polygons show the minimum perimeter and resultant activity area of tagged *Varanus bitatawa* caught and tracked in the Peñablanca Protected Land and Seascape (PPLS). Polygons with a thick border show activity area for males and polygons with a thin border for females. Axes are in Universal Transverse Mercator Easting (x-axis) and Northing (y-axis); details are removed to protect the exact location. Scale divisions on both axes are 20 m.

Tagged individuals moved in approximately straight line distances. Tracing lines from tagged individuals indicated that lizards traveled from one tree to another through the canopy jumping from heights of approximately 10 m. The lines showed that lizards sometimes scaled the same tree twice before moving on and that lizards used cavities and hollows at the bottom of trees and higher up within the trunk as hiding places. The nearest permanent human settlement (village) from the site of capture was 1.0 km in NSMNP and 7.0 km in PPLS. Despite the close proximity of settlements, we did not find evidence of movement of lizards into areas presently occupied by humans. We observed tagged individuals to move through old cleared forest areas of approximately 50 m in diameter. Lizards moved most frequently during the hottest part of the day; 83% of captures occurred between 1200 and 1459 and all trigger events capturing images of tagged lizards descending a tree occurred between 1000 and 1259.

Camera traps.—We placed cameras at 13 trap sites opposite trees sheltering a tagged *V. bitatawa* over a total of 58 d. Trap sites had a 46% success rate with six successful trigger events of three different tagged individuals descending the tree (Fig. 4). Of the seven sites that did not produce a trigger event, tagged individuals had not descended in front of the camera trap but had instead descended either on the opposite side of the trunk, had jumped from higher up the trunk or had moved through the canopy and descended down a different tree. It was not evident from the polyester trail that a camera had failed to trigger when a tagged individual

Table 3. Movement of *Varanus bitatawa* including mean and SD for all lizards tracked using spool and line tracking. Abbreviations are D_R = distance travelled on release to first tree, D_G = total distance travelled on the ground, D_T = minimum distance moved in trees, and D_{GD} = mean distance travelled on the ground per day (D_G/total number of days tracked).

Sex	SVL (cm)	Mass (kg)	D_R (m)	D_G (m)	D_T (m)	D_{GD} (m)	Total activity area (m^2)	Mean distance between trees ± SE (m)
F	40.0	1.0	70	326	549	82	2,600	37 ± 10.4
F	46.3	2.1	20	583	429	292	12,400	56 ± 12.6
F	50.0	2.5	16	166	434	53	500	185[a]
M	65.5	4.9	219	613	287	306	14,900	36 ± 20.3
M	64.2	5.1	82	892	783	149	31,600	81 ±26.5
Mean	53.2 ± 5.02	3.12 ± 0.81	81 ± 36.8	516 ± 125.3	496 ± 82.7	176 ± 52.5	12,400 ± 5,534	79 ± 27.7

[a] *n* = 1, only one recorded measurement for between trees movement.

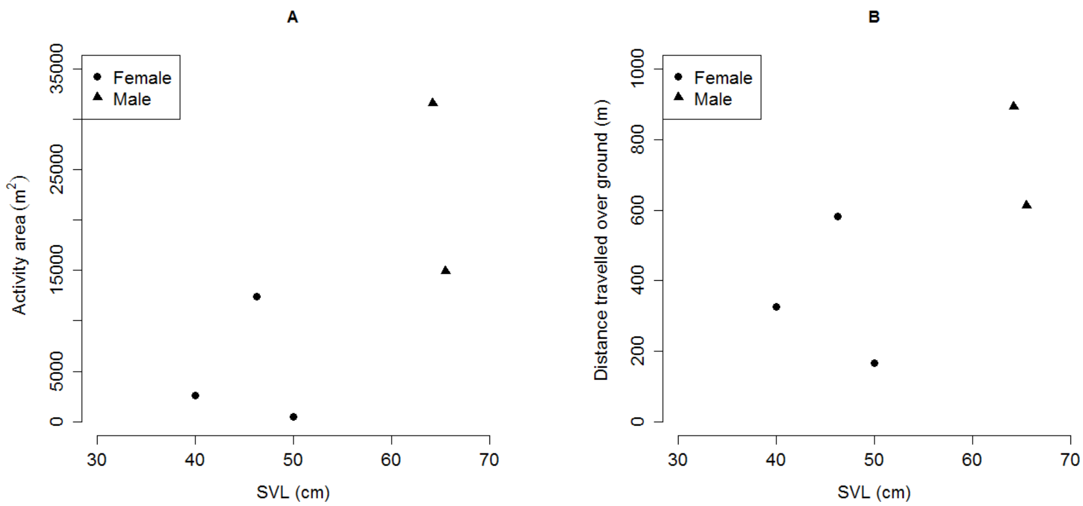

Figure 3. Relationship of activity area (A) and distance travelled over the ground (B) to snout-vent length (SVL) for *Varanus bitatawa*.

had moved in to the detection zone. The size of tagged individuals caught on camera ranged from 99.5–164.0 cm TL and 1.0–5.1 kg mass.

Discussion

Population density.—Due to the small sample size and short study period, behavioral and ecological traits reported here for *V. bitatawa* should be considered with caution, but, nevertheless, provide the first insights into their ecology. Due to the difficulty of identifying sex with certainty in the field, we recommend that results related to variations in sex are considered with caution as well. Data we collected on the morphometrics of six *V. bitatawa* and the subsequent information gained from following five of these individuals indicate that the observed ecology and biology of *V. bitatawa* is comparable to that of its sister species *V. olivaceus*. With a mean mass of 3.12 kg and mean TL of 132 cm of adults, *V. bitatawa* is similar in size to other adult frugivorous monitor lizard species: *V. olivaceus* found in Southern Luzon (Auffenberg 1988; Bennett 2000) and *V. mabitang* in Panay (Gaulke 2010). The largest *V. bitatawa* we caught was 163.5 cm long and had a mass of 5.1 kg, but an earlier measured *V. bitatawa* was 180 cm long and weighed 9 kg (Welton et al. 2010). The largest *V. mabitang* recorded had a TL of 175 cm and 8 kg (Gaulke 2010) while the largest *V. olivaceus* was 188 cm TL and 8.9 kg (Daniel Bennett, unpubl. data).

The mean activity area for *V. bitatawa* of 12,400 m^2 is comparable to that of *V. olivaceus* with a mean activity area reported as 5,000 m^2 for five individuals (Bennett 2000) to 14,800 m^2 for nine individuals (Auffenberg 1988). Estimates of activity area and home range increase with observation time and number of sightings used (Rose 1982), in this case the number of vector points and the duration of the tagged period. Estimates are also sensitive to movements on the periphery irrespective of the frequency with which that particular area is visited (MacDonald et al. 1980). If attention is given to the arboreal nature of *V. bitatawa*, then mean activity area would increase considerably. Auffenberg (1988) estimated that for the arboreal *V. olivaceus*, a mean range of 14,800 m^2 on the ground would increase to 148,000 m^2 when vertical range is included. Accordingly, if arboreal movement is accounted for, then activity area for *V. bitatawa* would be estimated at a mean of 124,000 m^2. The asymmetric activity area/home range between males and females found in this study (23,000 m^2 for males and 5,200 m^2 for females) is concordant with other studies of home ranges of varanids (Auffenberg 1988; Thompson 1994; Phillips 1995; Thompson et al. 1999). Sexual difference in activity area may be reflective of seasonal asymmetry in activity area rather than asymmetry observed throughout the year. Male varanids may range further during the breeding season to locate females to mate while smaller activity areas of females may be due to energy conservation (Auffenberg 1994; Phillips 1995; Thompson et al. 1999). The breeding season of *V. bitatawa* is yet to be established but is expected to be similar to *V. olivaceus*.

Recorded activity areas of tagged *V. bitatawa* were non-overlapping yet other *V. bitatawa* were sighted in the same area. Spatial overlap has been reported in *V. olivaceus* between individuals of the same sex and of different sexes, although more than one individual is rarely found in the shared area on the same day (Auffenberg 1988). The lack of spatial overlap shown here may be an artifact of the short study period and possible mutual avoidance shown by individuals in areas of

Figure 4. Camera trap image of a tagged female *Varanus bitatawa* in the Northern Sierra Madre Natural Park, Philippines, descending a tree used to shelter overnight.

overlapping range. Support for territoriality is reduced due to the observed shared use of the same fruiting tree by numerous individual *V. bitatawa*. Most of our captures of *V. bitatawa* occurred between 1200 and 1400, coinciding with reports from local hunters of a greater success in capture during midday; possibly because the hunting dogs are more likely to pick up the scent of recently moved lizards. Presuming that lizards spend the early part of the morning basking, it can be expected that greater levels of activity and movement would thus be observed at midday.

Although our small sample size precludes establishing a definitive relationship of distance travelled to size, both total distance travelled over ground and estimated activity area tended to increase with SVL. This is concordant with other lizard studies where a positive correlation of activity area and body size has been observed (Christian and Waldschmidt 1984; Thompson 1994). It has been postulated that home ranges may increase due to greater energetic requirements of larger lizards and larger areas are required by active foragers and herbivores (Perry and Garland 2002).

Linear movements between trees shown by *V. bitatawa* have also been reported in *V. olivaceus* (Bennett 2014) and the arboreal *Varanus tristis*, with individuals regularly returning to the same tree (Thompson et al. 1999). The distance travelled by *V. bitatawa* on the ground (D_G), in trees (D_T), and between trees (B_T) were greater than those recorded for *V. olivaceus* (D_G: 111 ± 24.3 m; D_T: 110 ± 36.0 m; B_T: 34 ± 5.8 m; Bennett 2000) using the same tracking method. We have not observed *V. bitatawa* returning to the same tree during our study but this may be due to the limitations of the short duration of the study. When *V. bitatawa* altered from straight line movements to circular ones, this tended to be over dead, rotten trees and we think this would occur when searching for insects and/or snails as part of the diet. Squamate reptiles that actively forage for food rather than ambush prey items are able to use chemical senses to detect food and discriminate prey items (Cooper 1995).

Our results suggest that the density of *V. bitatawa* is lower than the sympatrically occurring water monitor, *V. marmoratus*. Variation in ER may also be explained by differences in behavior and detectability between species. Both species are hunted (Besijn 2012), so shyness and human-avoiding behavior is expected to be comparable. *Varanus bitatawa* is primarily threatened by habitat destruction, with illegal logging of lowland forest continuing both inside and outside the Northern Sierra Madre Natural Park (van der Ploeg et al. 2011b) and by localized hunting (Besijn 2012). The appearance of *V. bitatawa* in the Philippine pet trade in 2012 (Sy 2012) indicates a potential new threat. A local conservation organization, the Mabuwaya Foundation, has started implementing *V. bitatawa* education and communication programs in local communities, modeled on their successful participative Philippine Crocodile conservation program (van Weerd and van der Ploeg 2012; van der Ploeg et al. 2011a).

The descriptive data presented here are a start in understanding the ecology of *V. bitatawa*, highlighting the similarities with its sister species *V. olivaceus*. More research is needed to fully understand *V. bitatawa* ecology. Perhaps more pressing is the need to study the distribution and population size of this species. *Varanus olivaceus* is assessed as Vulnerable and *V. mabitang* as Endangered on the International Union for Conservation of Nature and Natural Resources (IUCN) Red List (IUCN 2016) but *Varanus bitatawa* is not yet listed. Establishing a baseline estimate of population size and area of occupancy is imperative for assigning a conservation status to *V. bitatawa* to guide conservation initiatives.

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