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Communication

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PLATINUM OPEN ACCESS

Brief insight into the behavior, activity, and interspecific interactions of urban *Trimeresurus* (*Cryptelytrops*) *albolabris* (Reptilia: Squamata: Viperidae) vipers in Bangkok, Thailand

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Abstract: Green Pit Vipers are a widely distributed, diverse group of snakes which occur across a variety of habitats. Little is known about their natural history in anthropogenically modified environments, and no ecological work has investigated their persistence in cities. We non-invasively photo-monitored White-lipped Green Pit Vipers *Trimeresurus* (*Cryptelytrops*) *albolabris* in the metropolis of Bangkok, Thailand (n = 4 individuals, mean = 2,658 minutes per individual). Subsequently, we preliminarily characterize urban green pit vipers as nocturnal predators, displaying ambush-foraging at night, sheltering during the day, and having limited movement in between temporal periods. We recorded two predation events of vipers capturing and ingesting anuran prey. Vipers infrequently displayed tail undulations (239 minutes total), with one event occurring immediately before a predation event. We also document chemosensory, probing, and mouth-gaping behaviors having occurred exclusively at night. Other vertebrates including birds, frogs, geckos, small mammals, and a cobra were photographed interacting with focal vipers or their immediate surroundings (315 minutes total). Knowledge of organisms in tropical urban environments is scarce, and the persistence of venomous snakes in these unique and challenging habitats requires further study.

Keywords: Activity, behavior, conservation, White-lipped Green Pit Viper.

บทคัดย่อ: งูเขียวหางไหม้ (Green Pit Vipers) เป็นงูที่พบได้ในหลายพื้นที่และมีแหล่งอาศัยที่หลากหลาย แต่ความรู้ความเข้าใจในเรื่องของการปรับตัวให้เข้ากับสิ่งแวดล้อมของงูเขียวหางไหม้ก็ยังมีไม่มากนัก และที่ผ่านมายังไม่มีงานวิจัยทางด้านนิเวศวิทยาเกี่ยวกับการอาศัยอยู่ของงูเขียวหางไหม้ในเมืองอย่างจริงจัง ดังนั้นเราจึงทำการตรวจสอบพฤติกรรมของงูเขียวหางไหม้ท้องเหลือง (White-lipped Green Pit Vipers) ชนิด *Trimeresurus* (*Cryptelytrops*) *albolabris* ในเมืองหลวงกรุงเทพมหานคร ของประเทศไทย โดยการสังเกตุการณ์ผ่านถ่ายภาพ (จำนวน = 4 ตัว, เฉลี่ย = 2,658 นาที/ตัว) โดยเราพบว่า ลักษณะเฉพาะเบื้องต้นของงูเขียวหางไหม้ที่อาศัยอยู่ในเมือง คือ เป็นงูที่ซุ่มหาอาหารและล่าเหยื่อในเวลากลางคืน พักผ่อนในเวลากลางวัน และมีการเคลื่อนไหวอย่างจำกัดในระหว่างช่วงเวลาดังกล่าว ทั้งนี้กล้องของเราได้บันทึกภาพเหตุการณ์ระหว่างที่งูเขียวหางไหม้ล่าเหยื่อได้ 2 เหตุการณ์ ได้แก่ การจับเหยื่อ และการกินเหยื่อจำพวกกบ (anuran) ซึ่งงูเขียวหางไหม้จะไม่กระดิกหางบ่อยนักในเวลาปกติ (จากภาพบันทึกเหตุการณ์คิดเป็นเวลาเพียงแค่ 239 นาที) แต่เราพบการกระดิกหางเกิดขึ้น 1 ครั้ง โดยเกิดขึ้นทันทีก่อนที่งูจะจัดการกับเหยื่อ นอกจากนี้ เราได้บันทึกพฤติกรรมการรับรู้กลิ่น (chemosensory) การแลบลิ้น (probing) และการอ้าปาก (mouth-gaping) ซึ่งเกิดขึ้นมากเป็นพิเศษในช่วงเวลากลางคืน ทั้งนี้กล้องได้บันทึกภาพของสัตว์มีกระดูกสันหลังประเภทอื่นๆที่อาศัยอยู่ในบริเวณใกล้เคียงไว้ด้วยเช่นกัน ได้แก่ นก กบ ตุ๊กแก สัตว์เลี้ยงลูกด้วยนมขนาดเล็ก และงูเห่า (รวมทั้งหมด 315 นาที) อย่างไรก็ตาม ความรู้ความเข้าใจเกี่ยวกับพฤติกรรมของสิ่งมีชีวิตที่อาศัยอยู่ในสภาพแวดล้อมเมืองเขตร้อนยังมีไม่เพียงพอ เช่นเดียวกับการมีอยู่ของงูพิษในสถานที่อันมีเอกลักษณ์และความท้าทายเหล่านี้ก็มีความจำเป็นที่ต้องได้รับการศึกษาเพิ่มเติมในอนาคตด้วยเช่นกัน

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Author contribution: Both CHB and TKK conceived and designed the study concept, while TKK designed and implemented monitoring and data collection in the field. CHB lead the writing of the manuscript with significant guidance and contribution from TKK.

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INTRODUCTION

White-lipped Green Pit Vipers (*Trimeresurus* (*Cryptelytrops*) *albolabris*) are a widely distributed arboreal pit viper belonging to the genus *Trimeresurus,* which is comprised of over 40 species inhabiting various regions in Asia (Uetz & Hallermann 2015). At least eight species are currently known to occur in Thailand (Cox et al. 2012), with some species, like the Phuket Pit Viper (*Trimerersurus* (*Popeia*) *phuketensis*) becoming described as recently as 2011 (Sumontha et al. 2011). While the taxonomy and phylogeny of the genus *Trimeresurus* has largely been resolved (Malhotra & Thorpe 2004), genera and nomenclature designation remains unclear (David et al. 2011). Two species of green pit vipers, the Big-eyed Green Pit Viper (*T. macrops*) and White-lipped Green Pit Viper, inhabit Thailand's large metropolitan capital Bangkok (Cox et al. 2012).

Both, White-lipped and Big-eyed Green Pit Vipers have been previously reported to be responsible for 95% of the envenomating snake bites in the Bangkok metropolitan area (Meemano et al. 1987; Mahasandana & Jintakune 1990) and 30–40 % throughout Thailand (Viravan et al. 1992; WHO 2010). Despite being widely distributed throughout southern and southeastern Asia, little research has investigated the in situ ecology of green pit vipers. Work has largely focused on the habitat use, basic biology, and spatial ecology of radio telemetered Big-eyed and White-lipped Green Pit Vipers in rural or forested habitats (Devan-Song et al. 2016, 2017; Barnes et al. 2017; Strine et al. 2018). These studies, however, did not report data on the predatory behavior or interspecific interactions of White-lipped Green Pit Vipers in highly urbanized study sites. To address this knowledge gap, we utilized a time lapse camera to investigate and provide preliminary study of White-lipped Green Pit Viper behavior and activity patterns in Bangkok, Thailand. We also provide observations of syntopic organisms that were accidently photographed while vipers were present (or within 12 hours of abandoning sites) within this highly disturbed landscape.

METHODS

We surveyed for green pit vipers from a public roadway (Bangna Trad 19, Yaek 12), visually scanning vegetation where the road bordered a densely vegetated 0.20ha vacant lot (Image 1A). The property is located at (676494 E / 1512069 N; 47 P) in the Bangna District of Bangkok, Thailand. Dominant vegetation cover along the roadside and adjacent vacant lot predominantly consisted of non-native trees (*Leucaena leucocephala*), and vines (*Antigonon leptopus)*. We opportunistically surveyed for vipers after dark, beginning our searches at 21.00h between 30 October–16 November 2018. When a viper was located, we positioned a Bushnell field camera (Trophy Cam HD Essential E3, Model: 119837) with infrared night capability on a tripod spaced 1–2 m from each focal viper. We programmed the camera using a combined setting, including field scan, which continuously captured one photo every minute, along with motion sensor, which took photos upon movement trigger outside of the regular 1-minute intervals.

Only photos taken at the 1-minute intervals were utilized in our activity pattern analysis. The remaining pictures taken by the motion trigger were intended to be used as supplements (for identification and context) in the case of interactions and observations of or with other organisms. Care was taken when placing cameras to minimize our disturbance to the vipers.

Herein we report observations from four individual adult White-lipped Green Pit Vipers that had not abandoned their position in their photo frames within an hour of us setting the cameras. We left cameras stationed at the viper locations from their initial spotting at approximately 21.00h on the first night to 21.00h on the third night of monitoring, allowing two days and one full night (with one partial night after setting and one partial night before retrieving the camera) of photo observation without a visit from us to the site. We did not handle vipers and attempted to limit our disturbance to the habitat during camera setting by avoiding contact with connective vegetation. Upon camera removal on the third night, we also attempted to capture close-up images of each viper using Nikon D7000 camera to determine their sex (larger body and head size for females, and presence of a postocular stripe for males; Devan-Song et al. 2017) later (Image 1B). We monitored one viper per each two-day photo monitoring period because we were limited to one trail camera for field use. We determined that each individual we monitored was unique through general visual appearance, size, coloration/markings, and presumed sex.

We classified each time-lapse image with a green pit viper from our trail camera into one of four primary behavior states, defined as: ambushing, moving, resting, and sheltering following classification used by Strine et al. (2018). States are behaviors of relatively long duration (2 or more frames in our study (Martin & Bateson 2007). Ambush behavior was defined as maintaining a stationary

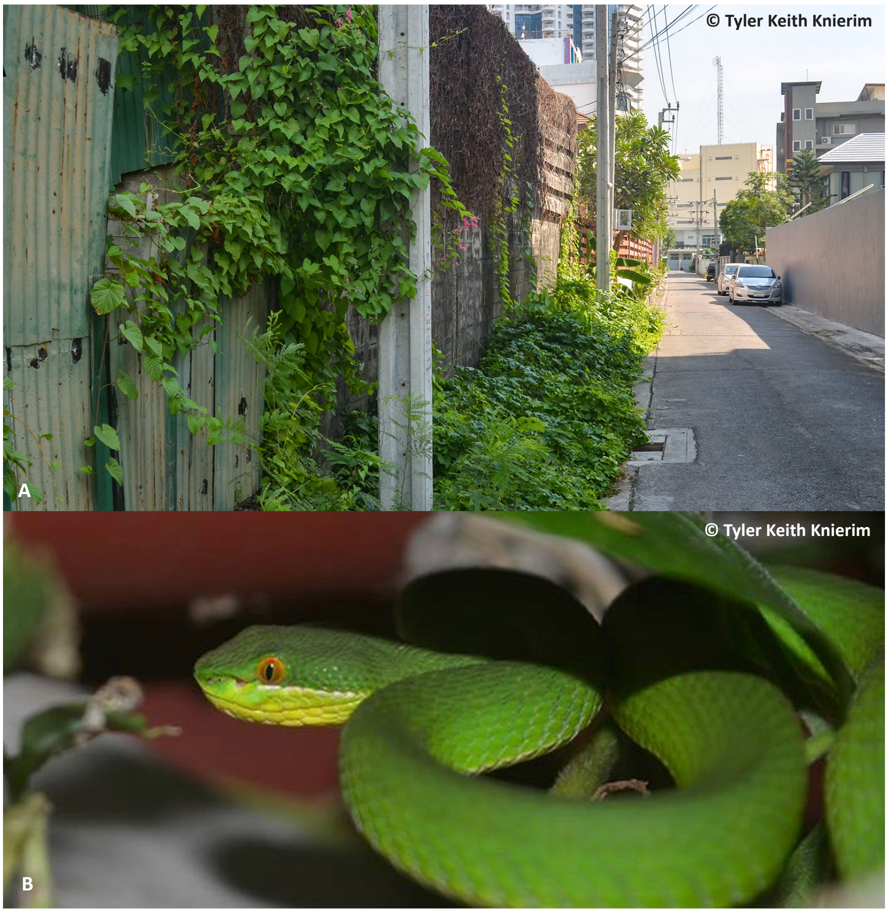

Image 1. A—Green Pit Viper habitat at survey site along Bangna 21 alleyway in Bangkok; B—an adult male White-lipped Green Pit Viper *Trimeresurus albolabris* (V3) ambushing towards a concrete wall within this environment.

foraging position, having a semi-coiled body with the head set in a bent neck, ready-to-strike position. Moving behavior was defined as a complete transference of the body of a viper from one site to another on camera frame or from a site on frame to off frame (or off camera to on camera). Resting was defined as having un-raised head settled on the body or habitat feature in what could best be described as a relaxed position. We classified a viper as being in a sheltering state only when it was not visible and other primary behaviors were not observable due to obstruction by vegetation or other habitat features. Additionally, we only defined behavior as sheltering if we could confirm both entrance and departure from the visually obstructing microhabitat feature on camera frame.

Other behavior states we observed, although infrequently, include feeding and tail undulation. Feeding was the behavior state used to collectively describe restraint and ingestion (until prey not visible and fully inside focal viper) processes of predation. We defined tail undulation similarly to Clark et al. (2016) as continuous, clear movement of the tail without pause for two or more consecutive time-lapse image scans (2 minutes).

Behavioral events (instantaneous behaviors, only observed for 1 frame in our study; Martin & Bateson 2007) irregularly observed in our study include mouth gaping and probing, which we defined similarly to Barbour & Clark (2012). A chemosensory probe (“probe”) was a clear (not blurred on camera, which could suggest a predatory strike towards prey) extension of the head beyond the body coil with a closed mouth towards a habitat feature. A mouth gape (“gape”) occurred when a viper opened its mouth at a ≥ 45˚ angle.

Behavioral events (probe and gape) and infrequently observed behavioral states (feeding and tail undulation) were recorded, but not included in our activity pattern analyses. We also attempt to document (but not analyse) all vertebrates observed on the cameras when vipers were present at or recently (within 12 hours) abandoned sites, so as to provide context for behaviors observed, potential prey and predators of green pit vipers, and general diversity in urban Bangkok; all of which have been scarcely studied prior.

We utilized the methodology developed by Ridout & Linkie (2009) to determine the daily activity patterns of vipers and quantify the amount of temporal overlap between active (ambush and movement) and inactive behaviors (resting and sheltering) using the 'overlap' package (Meredith & Ridout 2016) in program R (version 3.5.1; R Development Team 2018). First, a non-parametric circular kernel-density function was employed to assess comprehensively (summarized, since behaviors were discrete, i.e., only one behavior recorded at any given minute interval) daily activity patterns. Then a coefficient of overlap (Δ) was used to measure the extent of overlap between two kernel-density estimates, taking the minimum of the density functions from two sets of samples being compared at each point in time. Overlap was determined to be the area under both the density curves. The coefficient of overlap ranged from 0 (no overlap) to 1 (complete overlap) (Ridout & Linkie 2009; Linkie & Ridout 2011). We calculated the 95% confidence intervals of each overlap index using smoothed bootstrap with 999 resamples (Meredith & Ridout 2016).

RESULTS

In total, we set cameras for 10,628 minutes over the course of 11 days between 30 October and 16 November 2018 (mean 2,658 minutes per individual, n = 4, Table 1), which corresponds to the end of the rainy season in central Thailand (Singhrattna et al. 2005) and the end of the mating season for the species in Thailand (Chanhome et al. 2011). Vipers were positioned 10–50 cm above ground when recorded and generally moved out of frame when having left that height range.

We observed vipers ambushing for 2,872 minutes, sheltering for 467 minutes, and moving for 89 minutes. Ambush behavior was most frequently observed at night (18.00–06.00 h), sheltering during the day (under concrete buildings facing south and west, with about a 10cm opening with chunks of concrete wedged in), and movement occurring irregularly during both times (Fig. 1). Activity pattern overlap was minimal for active (ambush and movement) and inactive (sheltering) behaviors (Fig. 1, Δ = 0.05, CI = 0.08–0.10). Males were most frequently observed ambushing (77.0% of observations), then sheltering (20.3%), and moving least frequently (2.7%). Female vipers were most frequently observed ambushing (97.6%) and least frequently moving (2.4%), and never sheltering in frame (i.e., in immediate proximity to their camera location).

Table 1. Basic summary of our four focal White-lipped Green Pit Vipers *Trimeresurus albolabris* observed for 2,156–2,856 minutes each with proportion of active (ambush and movement behavior states) and inactive (resting and sheltering).

Viper ID	Sex	Time observed (in minutes)	Proportion active/inactive
V1	Female	2,156	1:0
V2	Female	2,803	1:0
V3	Male	2,817	0.67:0.33
V4	Male	2,856	1:0

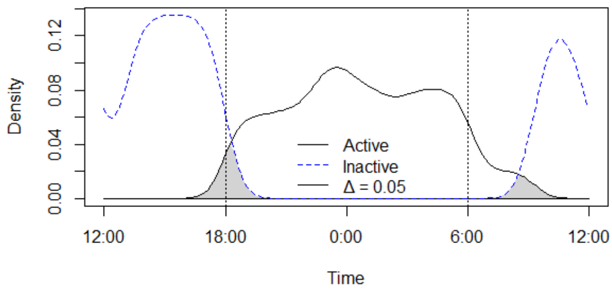

Figure 1. Density estimates of daily activity patterns of White-lipped Green Pit Vipers *Trimeresurus albolabris* in Bangkok, Thailand. Solid lines are kernel-density estimates for active behavior (ambushing and movement) observed, whereas dashed blue lines are inactive behavior (sheltering). Vertical dotted black lines indicate relative start of night (18.00h) and day time (06.00h). The overlapping coefficient (Δ) is represented by the shaded area.

Tail undulation was observed concurrently with ambush foraging behavior for 239 minutes by both females (176 minutes) and one male (V4, 63 minutes). It was observed in the presence of frogs (family: Microhylidae, likely genus *Microhyla*) for 17 minutes and in the presence of a single gecko (*Hemidactylus* sp.) for four minutes. One of the males (V4) was observed undulating for nine minutes (23.49–23.57 h) immediately preceding predation of one of the small frogs (at 23.58 h). The same male was also observed depredating a frog the following night (18.36–18.41 h, Fig. 2, 18 h 38 min between predation observations), although undulation was not observed immediately preceding the second predation event.

We observed 11 probing events by a single male (V4, 4min) and a single female (V2, 8min) viper, all of which were during the night time. Four mouth-gaping events were observed for a single male (V4, 3min) and a single female (V2, 1min), also all during the nocturnal hours.

Large rats (*Rattus* spp.) were visible on cameras for 10 minutes in the presence of two ambushing vipers (V1 & V3), both vipers appeared to react in response to the rat's activity. The rats were observed with refuse

Figure 2. Adult male White-lipped Viper (V4, circled) successful predation of a small frog (likely family Microhylidae).

or food (indistinguishable on camera) in their mouths for seven minutes. Both vipers pulled their heads back towards their body coil in response to all rats passing within approximately 30cm of their location. The male (V3) temporarily abandoned his ambush site during one interaction when a rat ran in front of his ambush target location. An adult Tokay Gecko *Gekko gecko* was visible within 50cm of viper for five minutes, which did not elicit a response from the focal viper (V3). The adult rats and Tokays were likely too large prey for the vipers in our observations, however, White-lipped Green Vipers have been recorded previously to eat small mammals and geckos (including other *Gekko* spp.; Chanhome et al. 2011; Devan- Song et al. 2017). Small (prey-sized) geckos (likely genus *Hemidactylus* or *Gehyra*, 6min) and frogs (family Microhylidae, likely genus *Microhyla*, 38min) were observed in the frame while vipers were ambushing.

One type of small frog (family Microhylidae, likely genus *Microhyla*, 181min) and another type (likely genus *Hylarana*, 2min) were visible on camera during which vipers were not present at ambush or shelter sites. Small (prey-sized) geckos (likely genus *Hemidactylus* or *Gehyra*) were observed for nine minutes. Large skinks (genus *Eutropis*) were visible on camera for 10 minutes during the daytime. Small passerine birds were observed for 15 minutes during the daytime (Oriental Magpie-Robin *Copsychus saularis*, 1min; Streak-eared Bulbul *Pycnonotus blanfordi*, 12min; unidentifiable species, 2min), and of these observations one minute featured two birds which perhaps suggested a mated pair (*P. blanfordi*). Large rats were visible for 38 minutes when vipers were not visible, of which one minute featured a rat with food or refuse. A Monocled Cobra *Naja kaouthia* was observed crawling directly past a viper's previous ambush site (11.33h) five hours and 30 minutes after a viper (V4) was observed ambushing; the same viper returned and resumed ambushing at the same site after nightfall, six hours and 27 minutes following the cobra observation. Knowledge of *N. kaouthia* diet is largely unpublished, however, they have been documented as preying primarily on snakes (but not green pit vipers, 21.7% of total diet composition), bird eggs (11.3%), and rodents (65.7%) in central Thailand (Chaitae 2000; summarized in Chanhome et al. 2011).

DISCUSSION

Our observations revealed novel and interesting insight into the persistence of an ambush-foraging snake species in highly degraded and disturbed habitat. During 11 days of camera monitoring, we witnessed multiple interactions (including predation events) and gained insight into behaviors and activity periods of green pit vipers in a previously unstudied habitat type (urban). We were able to confirm similar general behavioral trends between our city vipers and radio-telemetered White-lipped and Big-eyed Green Pit Vipers in rural and forested habitats in another region of Thailand (Strine et al. 2018; Barnes et al. in preparation). These behaviors are characterized by nocturnal active foraging (ambushing), diurnal inactive (sheltering), and infrequent short distance (within camera frame, < 0.5 m) movement primarily between ambush and shelter sites. Overlap of active (ambush and movement) and inactive (sheltering) behaviors was minimal, primarily limited to early evening and mornings (Fig. 1). Infrequently observed behaviors of suspected chemosensory function (probing and mouth gaping; Clark et al. 2016) were only observed nocturnally. Similar observation of active and chemosensory behaviors primarily during the night and inactive behaviors during the day by rural, natural forest, and urban vipers may suggest limited plasticity of White-lipped Green Pit Viper activity patterns, although retention of similar habitat (functionally, with the non-native trees and vines in Bangkok) and prey may partially explain similar behavior observed between habitat types. Urban White-lipped Green Pit Viper resting and sheltering behavior expression differed from previous observation of green pit vipers in natural forest and rural habitat, however.

Interestingly, we did not observe resting behavior by the city vipers; however, resting behavior has been frequently documented from green pit vipers in rural and forested habitats (Strine et al. 2018; Barnes et al. in preparation). We postulate that the vipers at our highly urbanized study site may prefer to rest in hidden shelters, rather than in the open as was observed from the vipers in the forested and rural studies. Additionally, vipers in our study only utilized terrestrial shelter sites (beneath cover objects) which may be unusual for what is usually characterized as an arboreal species. Phenotypic plasticity of organisms in natural habitats and urban environments has been documented for many groups of organisms with regards to shelter sites, foraging, and reproduction within the context of behavior (summarized in Lowry et al. 2012).

The vertebrate abundance that we observed on camera appears surprisingly high for such a disturbed habitat. We were able to observe multiple species of birds, geckos, lizards, frogs, and even a cobra, all of which may serve as potential prey (geckos, lizards, and frogs), predators (cobra), or antagonists (birds) to green pit vipers. Remote time-lapse cameras may thus provide an additional tool for sampling diversity in urban habitats. While none of the vertebrates photographed in our study are classified as threatened by the IUCN Red List, our cobra observation was significant as common cobras (monocle and spitting, *N. kaouthia* and *N. siamensis*, respectively) inflict approximately 23% of all venomous snakebites in Thailand (Warrell 2010).

We did not observe human-viper interactions during our short study. While large and charismatic snake species are frequently killed in Thailand (Marshall et al. 2018), a previous radio telemetric study suggests people in rural areas are tolerant of green pit vipers so long as they do not come into direct interaction (Barnes et al. 2017). Similarly, both in this work and a previous study (Barnes et al. 2017), vipers appear tolerant to the presence of people so long as they do not make physical contact (i.e., touch) with the snakes. Green pit vipers are responsible for inflicting the majority of venomous snake bites in Bangkok (approximately 95% of all bites; Meemano et al. 1987; Mahasandana & Jintakune 1990).

We strongly discourage long distance mitigation translocation (moving a snake from a site of conflict with people, to a different site outside of their home range) (Sullivan et al. 2014) due to limited activity and movement we observed in our work. A previous study of White-lipped Green Pit Viper in Hong Kong suggests non-natural (increased and erratic) movement, decreased fecundity, and significantly increased mortality of individuals resulted from being translocated outside of their home ranges (Devan-Song et al. 2017). Short distance mitigation translocation (within home range (Brown et al. 2009); previously suggested to be < 0.5ha area for White-lipped Green Pit Vipers (Barnes et al. 2017; Devan-Song et al. 2017)) or soft releases (gradual release with a limited acclimation period (Tuberville et al. 2005; Kingsbury & Attum 2009)) may suffice as less detrimental alternatives.

Although observations of large rats were infrequent on our cameras (only 48min total), all interactions (10min when vipers were present) elicited visible reactions from focal vipers. Both vipers (one male and one female) which interacted with rats clearly pulled their heads out of ambush position, while the male focal viper even temporarily moved away from his ambush site. We were unable to definitively discern the rat species observed on camera, although three *Rattus* species are known to be abundant in Bangkok, *Rattus norvegicus*, *R. exulans*, and *R. rattus* (Chotelersak et al. 2015); the Brown Rat *R. norvegicus* is an introduced species (Ruedas 2016). Interestingly, rat species in Bangkok have been suggested to utilize different habitats and different habitat features (*R. norvegicus* being primarily terrestrial and *R. exulans* usually confined to smaller villages, for example; Chotelersak et al. 2015), suggesting niche partitioning which could subsequently interact with and influence the behavior of White-lipped Green Pit Vipers (generally considered habitat generalists) differently depending on habitat type. While small mammals have previously been recorded as prey for White-lipped Green Pit Vipers (Chanhome et al. 2011), our study also suggests the direct disturbance by rats may play an important role in ambush site selection of green pit vipers in urban habitats. Additionally, we observed rats on camera (8min) carrying what appeared to be refuse or food, which may have been anthropogenic in nature and subsequently suggested human support of local rat populations. The abundance and influence of these various rat species, both native and introduced, on green pit viper foraging and activity patterns in the urban interface requires further attention.

Many green pit viper species possess orange or red colored tails. While, the function has not been widely discussed but defense and caudal luring may certainly be speculated. We categorized the behavior as tail undulation so as to be conservative in our assessment; however, we suspect the behavior to be a form of caudal luring. Although primarily observed when potential prey was not visible (218min), we also observed tail undulation in the presence of prey species (geckos and frogs, 21min) and immediately preceded one of the two predation events (9min, followed immediately by predation in the next scan/minute). Our observations support the functionality of tail colorations in luring prey, while Greene & Campbell (1972) and Greene (1973) proposed tail colorations to function as defensive warnings when used by *T. gramineus*. One of us (C. Barnes) has observed both functions for Big-eyed Green Pit Vipers (Barnes & Tipprapatkul 2019), which is sympatric in Bangkok and thought to be closely related to the White-lipped Green Pit Viper. Interestingly, vipers (White-lipped, Big-eyed, and Vogels Green Pit Viper *T. vogeli*) were rarely observed displaying tail undulation behavior (only one Big-eyed Green Pit Viper out of 21 individuals of several species studied on camera) in rural and forested habitats in a previous study (Barnes et al. in preparation), contrasting to most urban (3 out of 4 individuals) White-lipped Green Pit Vipers in this current report. Tail undulation and chemosensory behaviors could be investigated further in ex situ (under controlled laboratory conditions) vipers, using prey type and viper age as variables (refer to Reiserer 2002 for example with multiple other species of viper).

Snake behavior in urban environments remains poorly understood, particularly within the overall context of ecology. Future research into the behavior of green pit vipers in urban areas would benefit from investigation of the effects of non-natural lighting (i.e., streetlights) and vibration (from vehicle traffic or construction). Concurrent habitat assessment (characterization) and use, both natural and anthropogenic would prove invaluable. Whether or not the green spaces we observed White-lipped Green Pit Vipers to persist in serve as islands, bottlenecks, or ecological traps for the species could be revealed by population and genetic analysis. Previous camera study has suggested increased interactions and change in species occurrence of mesocarnivores with increased urbanization intensity (Parsons et al. 2019); more intensive (larger sample size during multiple seasons) work should be conducted to understand interactions among conspecifics (between and within sexes, age classes of White-lipped Green Pit Vipers), co-occurring green pit vipers (Big-eyed Green Pit Vipers, in Bangkok), and other native and non-native animals in tropical urban environments.

While our current work revealed brief but valuable insight into green pit viper ecology in tropical urban habitat, much work remains to properly characterize persistence and natural history in this unique and challenging environment. Further time-lapse camera studies would provide novel conservation and ecological information on green pit vipers and syntopic organisms in urban areas in tropical southeastern Asia. We strongly caution extrapolation from our preliminary observations and encourage more intensive (larger sample size over multiple seasons) investigation.

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