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Diet and Habitat Requirements of the Philippine Endemic Frugivorous Monitor Lizard *Varanus bitatawa*

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Abstract - Little is known about the ecology and diet of *Varanus bitatawa*, a recently discovered monitor lizard endemic to the Sierra Madre Mountains of Northern Luzon. Here we present data that show that it has a seasonal omnivorous diet comparable to its southern congener *Varanus olivaceus*. Consumption of fruits from *Pandanus* sp., *Canarium* sp. and *Microcos stylocarpa* was evident in fecal samples, from spool and line tracking observations, and from camera trap images. The frugivorous diet was supplemented with snails and insects belonging to the orders Orthoptera, Phasmatodea and Coleoptera. Habitat of *V. bitatawa* was studied in lowland disturbed dipterocarp forest at an elevation below 300 m. In three sampled sites basal area of dipterocarp trees ranged from 16.23 to 84.14 m^{2}ha^{-1}, total tree density from 624.6 to 1021.4 trees per ha^{-1} and density of *Pandanus* from 115.15 to 222.30 trees per ha^{-1}. Predominantly arboreal, *V. bitatawa* showed reliance on large sentinel trees. Of trees utilized, 47.4% were estimated at over 30 m tall with a mean circumference at breast height (CBH) of 176.28 cm and were significantly larger than the mean CBH of trees in sampled habitats. Shy and reclusive, *V. bitatawa* is likely to be vulnerable to disturbance. Illegal selective logging further degrades remaining habitat threatening the large dipterocarp trees on which they rely. Continued and improved protection of the forests within the Sierra Madre Mountain Range is imperative to safeguard the future of this restricted range species.

Introduction

The Philippines is identified as one of the world's 25 mega-diversity countries due to its exceptional concentration of endemic species (Mittermeier *et al*., 1998; Myers *et al*., 2000). With many endemic species threatened by habitat loss, the Philippines is also highlighted as a 'hyper hotspot' and a conservation priority (Myers *et al*., 2000; Brooks, 2002). Endemic to only a few islands within the Philippines are three species of arboreal, obligately frugivorous varanid lizards: *Varanus mabitang, V. olivaceus* and *V. bitatawa*. The untypical varanid feeding habitats of *V. mabitang* and *V. olivaceus* are well documented (Auffenberg, 1988; Struck *et al*., 2002; Bennett, 2008; Gaulke, 2010; Bennett, 2014) but information is lacking for the most recently described species, *V. bitatawa* (Welton *et al*., 2010). The unusual and specialized diet is likely a limiting factor for distribution of these endemic lizards. The allopatric distribution of *V. olivaceus* and *V. bitatawa* covers the southern and northern Sierra Madre mountain range respectively, a key biodiversity corridor in the Philippines containing 68% of all endemic genera and 40% of all remaining primary forest in the country (Antolin, 2003). This study is the first to describe the diet, use of trees and habitat requirements of *V. bitatawa* through field research.

Methods

Study site

The northern Sierra Madre mountain range runs along the eastern part of northern Luzon, Philippines, with the highest peak at 1844 m. above sea level. There is growing evidence of a biogeographical separation between the northern and southern Sierra Madre in Aurora Province (Welton *et al*., 2010). 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). Lowland forest here is dominated by dipterocarp species but has been disturbed by logging, even inside protected areas (van der Ploeg *et al*., 2011). In addition to lowland dipterocarp forest, the area has large areas of forest on ultrabasic soils and, in elevations over 800 m, montane forest (van Weerd & Udo de Haes, 2010). The northern Sierra Madre is emerging as one of the richest areas in terms of amphibian and reptile diversity in the Philippines (Brown *et al*., 2013). We collected data in disturbed lowland dipterocarp forest at three locations from June to August 2013. Two locations were within the Northern Sierra Madre National Park (NSMNP) in Isabela Province (locations A and B) approximately 3.0 km from the Pacific coast. One was within the Peñablanca Protected Landscape and Seascape (PPLS) in Cagayan Province (location C), further inland at approximately 6.0 km from the coast. We do not report precise locality data here to prevent collection of lizards by pet traders (Sy, 2012; Auliya *et al*., 2016), but locality coordinates have been deposited with the Mabuwaya Foundation, a conservation organization based in Isabela Province, Philippines. In all locations *V. bitatawa* surveys were carried out in disturbed, lowland dipterocarp forest on the eastern side of the mountain range at elevations below 300 m (Law *et al*., 2016). We caught six monitor lizards with the assistance of a local hunter. The hunter used a hunting dog to locate monitor lizards and captured them using a noose attached to a long pole from trees. One juvenile monitor lizard unfortunately was killed by a hunting dog. We used a spool and line tracking method (Bennett, 2000; Law *et al*., 2016) to follow movements of captured and released lizards and to determine which trees they visited. Diet studies and habitat characterisation studies were conducted in the three locations where *V. bitatawa* were captured.

Diet

Diet of *V. bitatawa* was investigated by tracking individuals tagged with the spool and line device. Trail threads were followed, fruiting trees climbed recorded and fecal samples along the thread trail collected. Moultrie Game Spy infrared cameras (model M-80XT; EBSCO Industries, Inc., Calera, Alabama, USA) were placed at fruit-bearing trees of species identified by local hunters to be important in the diet of *V. bitatawa*. Cameras operated continuously for 24 hours and were set at the highest sensitivity. Fresh fecal samples were collected from individuals during capture or from subsequent tracking. Items recovered from feces were identified to genus or species (for fruits) or order (for animals). Data on fruits identified as important dietary items were recorded. Ripe fruit were collected from fruiting trees, maximum length and width were measured using digital callipers and weighed using a spring scale.

Habitat requirements

To provide a quantitative description of the habitats used by *V. bitatawa*, tree density, cover in terms of basal area and relative frequency of trees were estimated using the Point-Centred Quarter Method (PCQM) (Mitchell, 2007). Transects were 200 m long running in an east-west direction and sampled every 10 m. The first transect was placed randomly near a *V. bitatawa* capture location; subsequent transects were systematically placed 50 m apart. Distance from each sampling point to the nearest living tree with a Circumference at Breast Height (CBH) above 30 cm in the four quadrats of a cartesian grid were recorded together with species, an estimation of height, and CBH at 1.3 m from the upper side of the slope. Multi-stemmed trees were recorded if the sum cross sectional area of individual stems at 1.3 m was greater than 30 cm. Distance between points was sufficient so that the same individual was not measured at two successive points during any survey. Trees were initially identified by names in local languages (Agta, Ilocano and/or Tagalog) and subsequently identified to scientific taxa (Merill, 1903; Guzman *et al*., 1986; Justo & Aragones, 1997, 1998; Justo, 1999; Pelser *et al*., 2011; Pelser, 2013). Assuming a random distribution of trees, an unbiased estimator of tree density for each area with 95% confidence intervals was calculated (Pollard, 1971; Seber, 1982; Mitchell, 2007). An importance value (sum of the three calculated measures of relative density, relative frequency and relative cover) was used as an indicator of the prevalence of each tree family within sampled habitats (Curtis & McIntosh, 1951). Values range from 0 to 300 where a higher value indicates greater importance. A score for endemism was assigned to trees identified to species level, (4-Endemic to Luzon, 3-Endemic to the Philippines, 2-Restricted range: found in some islands in Malaysia or Indonesia as well as the Philippines, and 1-Widespread throughout the Malay region).

Estimates of Pandanus density

Pandanus drupes are an important dietary item for all frugivorous monitor lizards (Auffenberg, 1988, Gaulke & Curio, 2001, Welton *et al*., 2010). Many *Pandanus* trees do not reach the minimum CBH of 30 cm to be included in PCQM surveys. Density of *Pandanus* was estimated using line transect distance sampling. Transects were 200 m long running in a north-south direction. The first transect was placed randomly near a *V. bitatawa* capture location, subsequent transects were placed systematically 50 m apart. Horizontal perpendicular distance to the center line of sighted trees was measured using a compass to fix the perpendicular line. Sightings of *Pandanus* were categorized as adults if a woody trunk was present at 1.3 m height or as juveniles if absent. CBH of any adult tree was recorded at 1.3 m height from the upper side of the slope. The total heights of all *Pandanus* trees were measured from the base of the trunk to the tip of a leaf using a tape measure when possible or estimated using a clinometer. Multi-stemmed *Pandanus* trees were treated similar to trees in the PCQM surveys. Sightings were recorded as clumps when the bases of each individual were confined within 1 m of each other. Perpendicular distance to the geometric centre of the clump was recorded. It was not possible to confidently identify the majority of *Pandanus* trees during sampling to species level, thus all density estimates given are for the family Pandanaceae. Density was estimated using DISTANCE 6.0 software. Three distance models (Half-normal, Hazard-rate and Uniform), each with various standard adjustments (Cosine, Simple Polynomial and Hermite polynomial), were fitted to each population. The data were right truncated at the largest observed distance. The most appropriate fitted detection model was selected based on the minimum Akaike Information Criterion (AIC), a delta AIC less than 2 and the largest goodness of fit probability value, tested by Chi-square (Burnham and Anderson, 2002).

Results

Diet of V. bitatawa

Five fresh fecal samples were collected and analyzed: two fecal samples were collected from caught *V. bitatawa* and three fecal samples were collected along trail threads during June and July. Fecal samples collected along trail thread were less than 24 hours old and attributed to the tagged individual. The stomach contents of one deceased juvenile were identified as far as possible. Fragments of snail shell and insect remains were counted as separate items when fragments looked visibly different. Fruits belonging to *Microcos stylocarpa* and species of *Pandanus* and *Canarium* were evident in fecal samples. *Varanus bitatawa* is not exclusively frugivorous and the nutritive value of fruits is enhanced with animals; 66.7% of dietary samples contained some animal remains.

Table 1. Composition of fecal and stomach content samples of *Varanus bitatawa* taken in June and July 2013 in northeast Luzon. *Microcos stylocarpa* seeds belong to the Malvaceae, *Canarium* seeds to the Burseraceae and *Pandanus* drupes to the Pandanaceae. The frequency of occurrence shows the proportion of samples that contained each food item.

Food item	Number of fragments/seeds within sample						Frequency of occurrence in samples (%)
	Fecal sample 1	Fecal sample 2	Fecal sample 3	Fecal sample 4	Fecal sample 5	Stomach sample 6	
Malvaceae	0	37	21	103	205	6	83.33
Pandanaceae	3	0	0	0	0	0	16.67
Burseraceae	1	0	0	0	0	0	16.67
Snail remains	0	0	0	1	3	1	50
Arthropod remains	0	0	1	0	1	3	50

Animal fragments in dietary samples were molluscs and insects of the orders Orthoptera, Phasmatodea and Coleoptera (Table 1). Fecal samples contained a mean number of 64.4 items per sample (range from 4-209) and a mean number of 2.8 taxa per sample (range from 1-5). The largest proportion of seeds found in all samples belonged to *Microcos stylocarpa* at 98.9%.

Camera traps were placed opposite four different fruiting trees (2 species of *Pandanus*, 1 species of *Canarium* and 1 *Microcos stylocarpa*) over 25 days. The camera tie opposite a *Canarium* tree was damaged, probably by Philippine forest rats, *Rattus everetti*. Only one trap site, opposite a *Pandanus* species, resulted in successful trigger events. All trigger events occurred between 0700 and 1559 h. A single camera placed for 7 days captured 8 trigger events including images of three different individuals ascending and descending the tree and a further two individuals captured ascending the tree only. Individuals were distinguished by variation in coloration patterns. Cameras had been set close to the predicted detection zone to increase the sensitivity of a trigger event but this resulted in images that did not include the whole body of the lizard, making size estimations of the lizard difficult (Fig. 1). Time spent in the *Pandanus* tree by three individuals ranged from 13 - 18 minutes, with a mean time of 16.3 minutes. This is

Fig. 1. Images of untagged *Varanus bitatawa* climbing the same fruiting Pandanus tree. Variation in dorsal patterns indicate that the images captured are of different individuals.

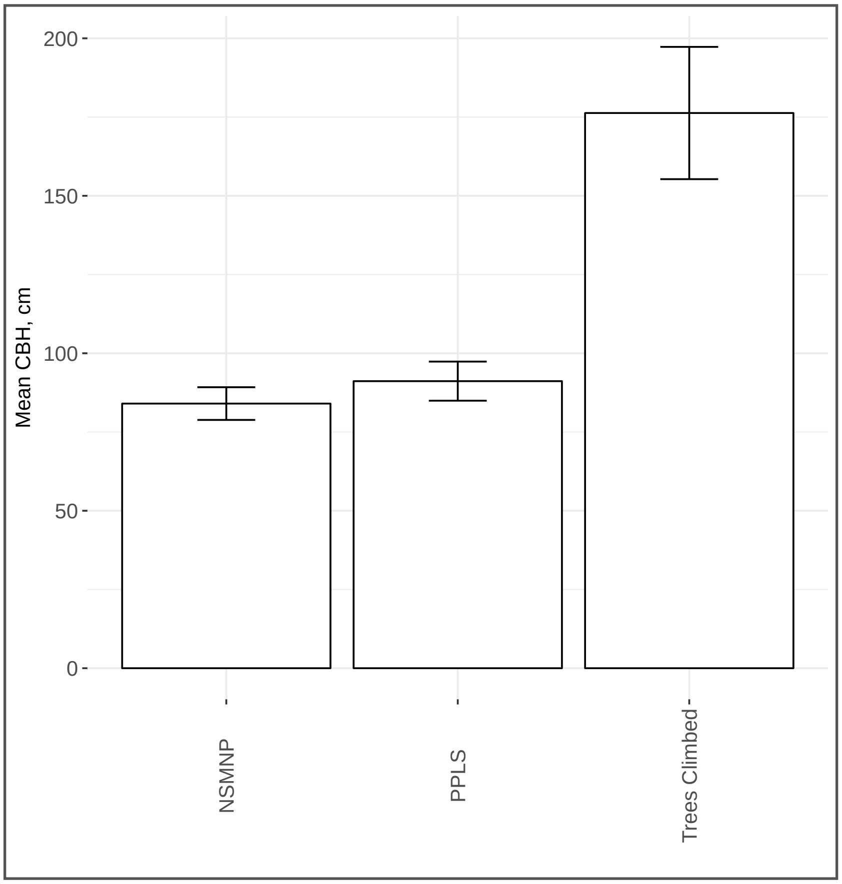

Fig. 2. Mean Circumference at Breast Height (CBH, in cm) with standard error bars of trees sampled in PCQM surveys in *Varanus bitatawa* habitat in the Northern Sierra Madre National Park (NSMNP) and the Peñablanca Protected Landscape and Seascape (PPLS) in northeast Luzon and the mean CBH of trees climbed by *V. bitatawa* in both areas.

longer than the recorded mean time of 13.5 minutes and 10.6 minutes spent in 2 different species of *Pandanus* tree by *V. olivaceus* (Bennett & Clements, 2014).

Tree Use by V. bitatawa

Tagged individuals were observed to travel from one tree to another through the canopy, to jump from heights of approximately 10 m, to scale the same tree twice before moving on and to use cavities and hollows at the bottom of trees and higher up within the trunk. Of trees utilized by spool and line-tracked *V. bitatawa* 48.7% belonged to Dipterocarpaceae, 17.9% were fruiting whilst 15.4% of trees used were dead. Emergent trees were used frequently; 47.4% of trees used were estimated at being over 30 m tall and 34.2% over 40 m tall. The mean CBH of trees used was 176.28 cm. This was significantly larger than the mean CBH of trees sampled in locations A, B and C which was 92.13 cm, 75.92 cm and 91.15 cm respectively (Kruskal-Wallis chi-squared = 28.96, df = 3, $p < 0.01$; Fig. 2). After log10 transformation, analysis of variance showed no significant difference in the CBH of trees used according to snout to vent length (SVL) of the tagged lizard, ($F[1,36] = 0.418$, $p = 0.522$). A two sample t-test revealed no significant difference between the CBH of trees used to shelter overnight and those used during the day ($t = -1.529$, df = 28.721, $p = 0.137$). Fruiting trees used were found to have a smaller CBH than non-fruiting trees (63.09 cm *vs* 201.84 cm), however small sample sizes preclude statistical analysis (7 vs 31).

Habitat of V. bitatawa

Two PCQM transects were completed in each location (A, B and C). Seventy-five different tree species were identified along all transects using the Ilocano or Agta name. The local names of two trees were not known. Of those recorded, 60% of trees were identified to species level, 67% to genus level and 69% to family level. It was not possible to assign scientific taxon names to 31% of trees. Frequent human use of the forest, particularly for hunting, was observed in all three locations. Surveyed forest within the PPLS and further inland had a higher mean endemic value and a much greater total basal area with larger dipterocarp trees indicative

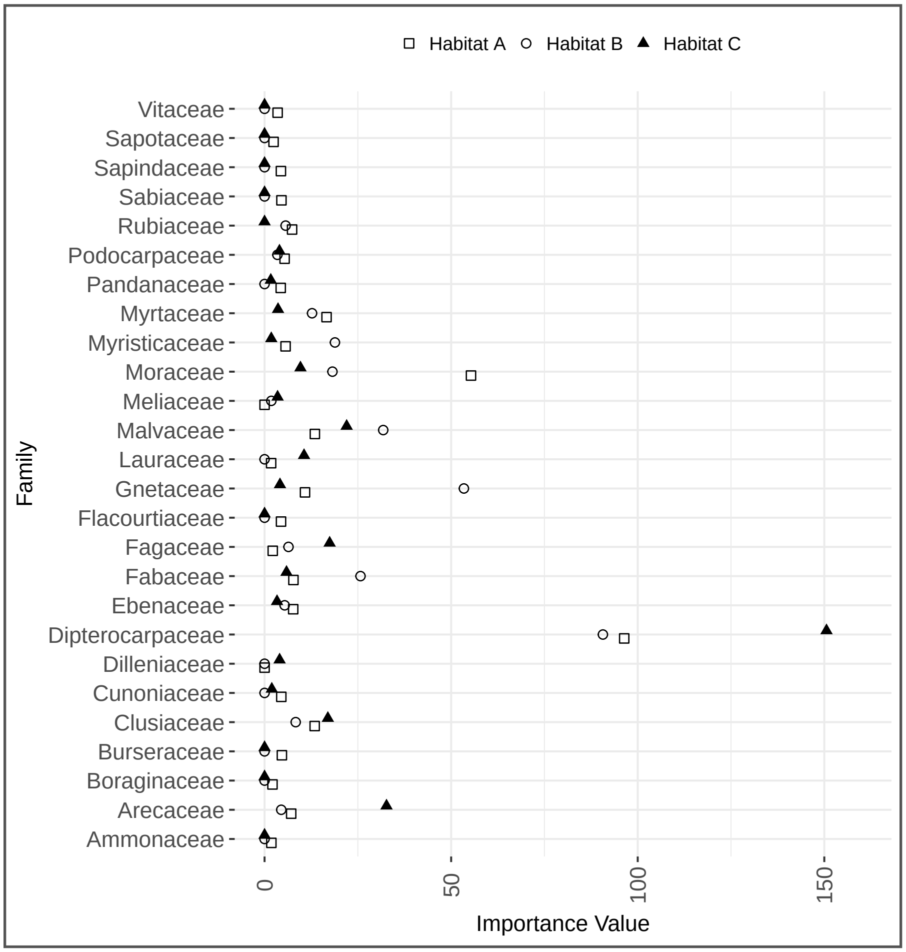

Fig. 3. Importance values for identified tree families in 3 three locations (A, B) within the Northern Sierra Madre National Park (NSMNP) and (C) in the Peñablanca Protected Landscape and Seascape (PPLS) in northeast Luzon where Varanus bitatawa were caught in 2013. Importance value = relative density + relative frequency + relative cover.

of less logging disturbance (Table 2). There was a high level of concordance in the importance of a number of families between locations (Fig. 3). Dominated by Dipterocarpaceae, other important trees within each location belonged to the families Moraceae, Gnetaceae, Arecaceae and Malvaceae. *Microcos stylocarpa* belonging to Malvaceae, identified as an important food item to *V. bitatawa* in this study has a relatively high importance value across all three locations. Exclusion of trees with a CBH < 30 cm during sampling effort omitted most Pandanaceae from the PCQM survey. Fruits from Pandanaceae were identified as of dietary importance to *V. bitatawa* in this study. Line distance sampling of Pandanaceae showed the density of *Pandanus* trees to be

Table 2. Comparison of habitat characteristics in three sampled locations (A, B and C) within the Northern Sierra Madre National Park (NSMNP) and the Peñablanca Protected Landscape and Seascape (PPLS) in northeast Luzon where *Varanus bitatawa* were caught in 2013.

	Location A in NSMNP	Location B in NSMNP	Location C in PPLS
Mean endemic value	1.8	1.8	2.2
Mean distance between trees (m)	3.9	3.1	3.2
Mean CBH (cm)	92.13	75.92	91.15
Tree density (trees per ha^{-1}) / 95% CI	624.6 (534.2–728.8)	1021.4 (873.3–1191.5)	882.9 (754.8–1029.9)
Total basal area (m^2ha^{-1})	28.88	59.16	104.54
Basal area of dipterocarp trees (m^2ha^{-1})	16.23	25.71	84.14
Basal area of non-dipterocarp trees (m^2ha^{-1})	12.65	33.45	20.43

Table 3. Estimates of Pandanaceae tree density in three locations (A, B) within the Northern Sierra Madre National Park (NSMNP) and (C) in the Peñablanca Protected Landscape and Seascape (PPLS) in northeast Luzon where *Varanus bitatawa* were caught in 2013. Density estimate = mean ± standard error; Hn/C=Half-normal/Cosine, Hn/P=Half-normal/Simple Polynomial, Hr/C=Hazard-rate/Cosine, Hr/P=Hazard-rate/Simple Polynomial, U/P=Uniform/Simple Polynomial. AIC=Akaike Information Criterion; GoF=chi squared goodness of fit probability value; 95% confidence interval (CI); ESW = distance effective strip width used.

Location	Tree Population	Density	Encounter Rate	Distance Model Parameters			95% CI		ESW (m)
		(trees per ha^{-1})	(trees per m^{-1})	Model/Series	AIC	GoF (p-value)	Lower	Upper	
A	All	115.15 ± 19.02	0.14	Hn/C	817.63	0.84	78.06	169.85	7.42
	Adults	16.09 ± 7.14	0.03	Hr/C	185.2	0.86	5.94	43.58	8.8
	Juveniles	122.3 ± 24.42	0.11	Hr/P	625.03	0.7	81.94	182.55	5.83
B	All	140.95 ± 37.34	0.12	Hr/C	614.97	0.14	74.68	266	5.94
	Adult	16.65 ± 5.59	0.02	Hn/P	133.63	0.13	7.81	35.49	7.26
	Juveniles	123.34 ± 33.29	0.1	Hr/C	468.84	0.12	64.52	235.78	5.81
C	All	222.3 ± 53.46	0.35	Hr/P	2162.74	0.06	122.68	402.84	8.92
	Adults	89.79 ± 21.19	0.17	U/P	1105	0.15	49.66	162.34	9.61
	Juveniles	136.04 ± 35.39	0.17	Hr/C	1048.4	0.08	72.53	255.15	8.24

greater further inland. Estimated density of *Pandanus* was highest in the PPLS, with a total density between 1.6 and 1.9 times greater than in the NSMNP. Density of adult *Pandanus* was between 5.4 and 5.6 times greater indicating a higher abundance of *Pandanus* fruit available for *V. bitatawa* in the PPLS (Table 3).

Discussion

Fecal samples of *V. bitatawa* showed a diet during June and July reliant on the fruits of *Microcos stylocarpa*, *Pandanus* and *Canarium* with the occasional inclusion of invertebrates including molluscs and insects of the orders Orthoptera, Phasmatodea and Coleoptera. By far the largest proportion of seeds (98.9%) within dietary samples belonged to *Microcos stylocarpa,* in fruit at the time of sampling, indicating that diet is likely to vary seasonally with fruit availability. The fruits of *Pandanus* form large drupaceous syncarps with a hard, waxy pericarp while *Canarium* fruits are stony drupes. Both are oily which contrasts with the sugary, berry fruit of *Microcos stylocarpa*. The comparatively smaller size (Table 4) and possible lower calorific value of the fruit of *M. stylocarpa* may account for the larger numbers consumed.

Also, *Microcos stylocarpa* has a short and highly synchronized fruiting season, much shorter than *Pandanus* or *Canarium*. It is likely that fruits such as those from *Microcos* are a preferred diet item of *V. bitatawa* during the short time they are available while fruits of species with longer fruiting seasons constitute the main diet items in other periods of the year. Consumption of orthopterans and coleopterans conforms to the diet of most other varanids as commonly eaten items of high energetic importance (Losos & Greene, 1988), *V. bitatawa* supplement this further with snails. Low numbers of animal remains may be related to the availability of fruit during the months sampled of June to August. Auffenberg (1988) also reported that fewer animals were consumed by *V. olivaceus* during June to August. Although our results are limited for a short period of the year, they constitute the first information on the diet of *V. bitatawa*.

The diet of *V. bitatawa* is similar to that of its sister species *V. olivaceus*, supplementing fruit with animals (Bennett, 2008) rather than the strict herbivory and folivory diet indicated by low levels of nitrogen isotopes reported in *V. mabitang* (Struck *et al*., 2002; Gaulke, 2010). It is conjectured that frugivorous varanids are able to consume fruits of *Canarium* as they are able to detoxify high levels of secondary compounds found in these fruits, such as calcium oxalate, that many other vertebrates may find difficult to digest (Auffenberg, 1988). In the absence of other consumers, *V. bitatawa* may play an important ecological role as a seed dispersing agent for plants in this genus. *Pandanus* distribution has been linked to the dispersal of seeds in feces of *V. olivaceus*, occurring uphill of parent plants, on hill tops and along ridges (Bennett, 2008; Reyes *et al*., 2008). Any significant decline in the population of frugivorous varanids could subsequently significantly impact the distribution of some of the plants on which

Table 4. Comparison of characteristics of fruit identified as important dietary items of *Varanus bitatawa* in June- August 2013 in northeast Luzon. Fruit samples were taken from fruiting trees along trail threads of tracked *V. bitatawa*.

Fruit	Sample size	Length (mm)	Width (mm)	Mass (g)
Pandanus sp. 1	16	61.78	14.37	4.94
Pandanus sp. 2	12	38.63	26.93	14.92
Canarium sp.	12	29.88	21.42	7.71
Microcos stylocarpus	30	14.81	9.31	0.77

it feeds.

The habitat of *V. bitatawa* tracked in this study was characterised as lowland dipterocarp forest on steep and mountainous terrain. A greater mean basal area of all trees and of Dipterocarpaceae further inland in location C in the PPLS is indicative of fewer disturbances by logging and of a greater number of large trees. These figures are higher than the remaining primary forest on Polillo (Bennett, 2008) used by *V. olivaceus* where the mean basal area of all trees is 64.99 m^2ha^{-1} (*vs* 104.57 m^2ha^{-1} in PPLS) and of Dipterocarpaceae 33.98 m^2ha^{-1} (*vs* 84.14 m^2ha^{-1} in PPLS). Secondary forest in Polillo is more similar to the coastal disturbed forest habitats recorded here (Locations A and B in the NSMNP) with much lower values of mean basal area of all trees and of Dipterocarpaceae of 45.72 m^2ha^{-1} (*vs* 28.88 m^2ha^{-1}in NSMNP) and 15.12 m^2ha^{-1} (16.23 m^2ha^{-1} in NSMNP), respectively (Bennett, 2008). The presence of large, sentinel trees in the habitat of *V. bitatawa* is important for shelter and to bask rather than as a food source. *Varanus bitatawa* selected trees to climb with a mean CBH of 176.28 cm, significantly larger than the mean CBH of trees recorded during surveys of the area and larger than the mean CBH of trees used by *V. olivaceus* in Polillo at 132 cm (Bennett, 2000). *Pandanus* trees are usually omitted in floral surveys (Co, 2006) and there is an absence of reports on the density of *Pandanus* in forested areas. Adult *Pandanus* trees were present at a much higher density inland, further from human habitation, at 89.79 adult trees per ha^{-1} compared to 16.09 adult trees per ha^{-1}.

All habitats in which *V. bitatawa* were found showed some level of disturbance, reflecting the absence of completely undisturbed lowland forest in the northern Sierra Madre as a result of selective illegal logging. However, sightings were at least 1.0 km from the nearest permanent human settlement and there were no reports of sightings within settlements or in agricultural land indicating vulnerability to disturbance or an inability to persist in areas with regular human activity. This is concordant with findings from studies of local ecological knowledge where 97% of respondents reported that *V. bitatawa* were never seen in close proximity to settlements (Besijn, 2012). It can be postulated that the habitat of *V. bitatawa* is primarily good quality lowland dipterocarp forest where large sentinel trees such as *Shorea* remain. However, as forests have become increasingly disturbed and fragmented, *V. bitatawa* have persisted because preferred fruiting trees have not been logged. This observation is comparable to that given by Bennett (2000) for *V. olivaceus*.

In 2018, *V. bitatawa* has not yet been assessed for the IUCN red list. Its congeners *V. olivaceus* and *V. mabitang* are listed as vulnerable and endangered respectively (Gaulke *et al*., 2009; Sy *et al*., 2009). The declining population of its congeners, and primary threats to *V. bitatawa*, are attributed to human encroachment. Although hunting of any wildlife without a permit is not allowed in the Philippines under the Wildlife Act or Republic Act No. 9147 (Republic of the Philippines, 2001a), hunting of monitor lizards is widespread and largely uncontrolled for personal consumption and the bushmeat market (Besijn, 2012; Welton *et al*., 2013) and for the pet trade (Sy, 2012). Against this, within the NSMNP hunting by indigenous people and tenured migrants (people living inside the NSMNP since before 1992) is allowed for traditional use, domestic needs and subsistence, albeit with unclear provisions about permits, under the NSMNP Act or Republic Act No.9125 (Republic of the Philippines, 2001b). Within the PPLS, which is under the National Integrated Protected Areas System (Republic of the Philippines, 1992), hunting of monitor lizards is not allowed. Cutting of trees for timber or agricultural conversion is not allowed anywhere without a permit. Irrespective of legislation, illegal logging (Van der

Ploeg *et al*., 2011) and forest conversion for agriculture (Verburg *et al*., 2006) continue to threaten protected areas in the northern Sierra Madre. The removal of large, emergent dipterocarp trees targeted by loggers is less likely to hinder food supply for *V. bitatawa,* but would result in fewer sentinel trees that are used for basking, refuge and sleeping. Forcing *V. bitatawa* to shelter in smaller trees as larger trees are logged renders them more visible and thus more vulnerable to hunting. The 2011-2016 Regional Development Plan for Cagayan Valley identifies growth in infrastructure to improve the accessibility and mobility within the region as a priority. This includes the development of a road connecting the western valley side to currently isolated eastern coastal settlements (Regional Development Council Region 02, 2011). Road construction from Ilagan to Divilacan began in March 2016 and is due for completion in 2018. This 82 km road cuts through the foothills of the NSMNP with the threat of further fragmentation of the forest, loss of *V. bitatawa* habitat and increased accessibility to the forest of the northern Sierra Madre for loggers, farmers and hunters. To safeguard the future population of *V. bitatawa*, hunting of this species must be controlled. In addition, the protection of remaining *V. bitatawa* habitat consisting of undisturbed or little disturbed lowland dipterocarp forest with large, sentinel trees and *Microcos stylocarpa*, *Pandanus* and *Canarium* trees is imperative.

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