BIAWAK

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On the Cover: *Varanus giganteus* and Echidna

The mummified *Varanus giganteus* and echidna (*Tachyglossus aculeatus*) depicted on the cover and inset of this issue is part of an exhibit on display at the Queensland Museum, in Brisbane, Australia. According to the museum, the *V. giganteus* died while attempting to ingest the echidna, and the arid environment provided conditions that led to their partial mummification. The specimens were acquired for display prior to 1912.

Varanus giganteus is Australia's largest extant varanid lizard, attaining a maximum length of over 2 m. It occurs throughout the arid center of Australia ranging from the west coast to central Queensland, and preys upon a variety of vertebrates and invertebrates including other reptiles, birds and mammals.

The image shown the right and on the cover of this issue, entitled "*Choke Hold*", was taken by lamont_cranston in 2008 and is licensed under CC BY-NC-SA 2.0. The image below (cropped), entitled "*Locked in Death's Embrace*", was taken by Orin Zebest in 2006 and is licensed under CC BY-SA 2.0.

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INTERNATIONAL VARANID INTEREST GROUP
www.varanidae.org

The International Varanid Interest Group is a volunteer-based organization established to advance varanid research, conservation, and husbandry, and to promote scientific literacy among varanid enthusiasts. Membership to the IVIG is free, and open to anyone with an interest in varanid lizards and the advancement of varanid research. Membership includes subscription to *Biawak*, an international research journal of varanid biology and husbandry, and is available online through the IVIG website.

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Varanus nuchalis. Photographed by **Laurence Paul**.

Construction Worker Bitten by Komodo Dragon

A construction worker was bitten on the right hand and leg by a Komodo dragon (*Varanus komodoensis*) on the island of Rinca, Indonesia while attempting to repair a toilet in the office of Loh Buaya Resort. The victim was taken by boat to a hospital where he received stitches. No information was made available on how the dragon gained access to the office, though the animals are commonly seen frequenting the village. A spokesperson for Komodo National Park noted that a total of thirty-one individuals have been injured by dragons within the park, going back to the death of the Swiss Baron Rudolf Reding von Biberegg in 1974, and that there have been five fatalities. However, the number of dragon attacks over the years has been poorly recorded and many sources (including that of Walter Auffenberg) give higher figures.

Source: The Jakarta Post; 1 December 2017

Suspect Arrested for Illegal Trade in Philippine Monitor Lizards

A 24 year-old man was arrested by officials from the Department of Environment and Natural Resources and the National Bureau of Investigation for allegedly selling illegal wildlife in Cebu City, Cebu, Philippines. The arrest came following the raid of a house in Cebu City which revealed a live juvenile monitor lizard (species not specified) and an albino Burmese python in enclosures. The suspect's illegal trade activities had been monitored through social networking sites for a week prior to the raid. According to officials, the suspect admitted to selling monitor lizards in the past, but claimed to have stopped after deciding to keep them as pets. The suspect lacked permits to sell or keep endangered animals as pets.

Officials note that illegal wildlife traders have mostly been shipping monitor lizards to the United States by concealing them inside stuffed animal toys or in computer equipment. The confiscated animal was taken to a local wildlife rescue center in Cebu City.

Source: Cebu Daily News; 14 July 2017

Fort Worth Zoo Announces Hatching of Komodo Dragons

The Fort Worth Zoo (USA) has announced the successful hatching of eleven Komodo dragons (*Varanus komodoensis*). Hatching occurred in October, but was not publicized until late November to ensure that the animals were acclimated and eating regularly. These offspring were produced by a pair of adults that arrived at Fort Worth Zoo in 2012; the female was originally from Prague Zoo (CZ), while the male was originally from the Denver Zoo (USA). Zoo officials plan on keeping one or two of the hatchlings and transferring the rest to other facilities in the future.

Source: Star-Telegram; 27 November 2017

Flourishing Online Trade in Varanid Sex Organs

During a joint operation in September 2017 by the Wildlife Crime Control Bureau (WCCD) and the Odisha Forest Department of the state of Odisha, eastern India, 34 pairs of varanid lizard hemipenes were confiscated along with other wildlife parts. The hemipenes, referred to as “hatha jodi”, are peddled as a rare plant root in occult shops as it is purported to have magical powers and ensure prosperity for whoever owns it. Additional seizures of varanid hemipenes have been made in Gujarat, Madhya Pradesh, Uttar Pradesh and Odisha in 2017, signaling a sharp increase in the trade of this product. Online, the hemipenes, advertised as sacred roots, sell for between Rs 1,200 and 2,200 (US $17-32).

Source: The Indian Express; 14 September 2017

Death of Colchester Zoo's Komodo Dragon

Colchester Zoo's male Komodo dragon (*Varanus komodoensis*) has died. The 10 year-old animal, named Telu, was originally from Prague Zoo before arriving at Colchester in 2010. Telu produced twenty-four offspring during his time at Colchester, which were the first dragons to be bred in the UK utilizing natural methods of reproduction. As the death occurred suddenly and with no noted history of illness, zoo officials have performed a necropsy, though the results have not yet been made available.

Source: Essex Live; 23 November 2017

Monitor Lizard Removed from Train Depot in Singapore

An Asian water monitor (*Varanus salvator macromacultus*) created a commotion at the Bishan SMRT train depot in Singapore when it was discovered hiding in the undercarriage of a parked train. Depot workers used sticks to coerce the animal out of its hiding area where it could then be captured and removed. These efforts were later criticized by online commenters for their rough handling of the animal when video of the capture was posted online, suggesting that experienced wildlife rescuers should have been requested.

Source: www.upi.com; 29 November 2017

Paignton Zoo Welcomes *Varanus macraei*

The Paignton Zoo (UK) recently added four blue tree monitors, *Varanus macraei*, to its collection, noting that this is the first time the species has been kept by the zoo, and only three zoos in the United Kingdom currently display the species. The addition follows the recommendation of the European Reptile Working Group that more European zoos should be working with this species. All four individuals, each around five years in age, are now on display in the zoo's reptile nursery.

Source: www.devonlive.com; 28 November 2017

Varanus exanthematicus, Dawa, Ghana, March 2018. Photographed by **Daniel Bennett**.

Bengal Monitor Captured at Heathrow Airport

On 17 January 2018, a juvenile Bengal monitor (*Varanus bengalensis*) was captured by Border Force officials in Terminal 4 of London's Heathrow Airport. The animal had been spotted by baggage handler staff in Terminal 4, which sees several flights arriving from India and south Asia daily. Although the origins of the animal and the nature of its transport are unknown, officials suspect that it may have been placed in luggage in an attempt to smuggle it into the United Kingdom illegally. The animal was transferred to a wildlife specialist center near Heathrow, where officials will then look to find a suitable permanent home for it.

Source: www.hindustantimes.com ; 23 January 2018

Kyrgyzstan to Create National Park to Protect Monitor Lizards

Officials from the State Agency for Environmental Protection and Forestry of Kyrgyzstan announced plans at the recent international seminar for Central Asian states on the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES), to establish a new national park in the Batken region of southwestern Kyrgyzstan to help protect the Caspian desert monitor (*Varanus griseus caspius*). Kyrgyzstan is presently home to 13 parks and 10 reserves, which are designated as special protected areas.

Source: www.akipress.com; 22 May 2018

California Man Sentenced for Smuggling Philippine Monitors

A 34-year-old California man was sentenced to six months of house arrest and three years of federal probation for his involvement in smuggling five Philippine monitor lizards into the United States in 2017. The individual pleaded guilty in September 2017 to a single federal account of smuggling the lizards.

In 2017, federal customs officials intercepted a package originating from the Philippines labeled as "speakers" that was addressed to the individual's son. Inside, authorities found a Samar water monitor (*Varanus cumingi samarensis*), a Palawan water monitor (*V. palawanensis*) and three spiny-necked water monitors (*V. nuchalis*). Two of the lizards arrived dead, and a third had a damaged foot. A subsequent search warrant carried out by USFWS at the individual's residence resulted in a further seizure of four *V. cumingi* and two *V. nuchalis*.

All monitor lizard species are protected under CITES. The smuggling of monitor lizards into the United States may be on the rise, as officials note that this case represents one of three cases involving monitor lizards prosecuted by US attorneys since the previous winter. Officials valued the monitor lizards in the present case at US $1,500 to $2,000 each.

Source: www.dailynews.com; 29 March 2018

Indian Man Arrested for Smuggling Monitor Lizard Sex Organs

A fifty year-old man was arrested by Madhya Pradesh Forest Department officials for his involvement in the illegal inter-state trade of monitor lizard sex organs in India. Officials apprehended the suspect after receiving a tip-off about his presence in Katni and Panna districts. The suspect, Pawan Pardhi, is a notorious wildlife smuggler and poacher that has been wanted by police and wildlife officials in India for nearly two decades.

The dried hemipenes of monitors (*Varanus bengalensis*), called "Hatha Jodi" are sold as rare plant roots that are purportedly used in tantric rituals as an aphrodisiac. This arrest represents a growing trend in cases involving monitor lizards in India, with a previous case in Madhya Pradesh involving the arrest of a temple priest and four traders for selling Hatha Jodi online. Additionally, four online companies have been reprimanded for trading in these parts.

Source: www.hindustantimes.com; 8 March 2018

Citizen Science Project Seeks to Survey Eyre Peninsula Goannas

Researchers with the Natural Resources Eyre Peninsula are seeking assistance from the local community to survey for goannas on the Lower Eyre Peninsula of South Australia. This effort is part of the Eyre Peninsula Goanna Citizens Science Project, which has been running for two years and has generated more than 1,000 sightings to date. The data collected seeks to provide insight into the ecology, survival and movements of the two native species of goanna (*Varanus rosenbergi* and *V. gouldii*) throughout the landscape. Much interest lies in generating data for certain areas including the areas of Wangary, Coulta, Sleaford, and Lincoln and Coffin Bay National Parks.

Source: www.portlincolntimes.com.au; 12 December 2017

Surabaya Zoo Hatches Komodo Dragons

The Surabaya Zoo, on Java, Indonesia recently announced the hatching of 11 Komodo dragons (*Varanus komodoensis*) between 27 February and 10 March 2018, bringing the zoo's captive *V. komodoensis* population to 76 individuals. The recent hatchlings originated from a total of 28 eggs produced by three females. Zoo officials suspect that poor maternal nutrition may be responsible for the low hatch rates observed.

Source: www.thejakartapost.com; 19 March 2018

Penalties for Tour Guides Who Disturb Komodo Dragons

Officials from Komodo National Park, Indonesia have announced plans to revoke the licenses of tour guides visiting the park if they are observed violating their licenses by taking tourists to inappropriately interact with the park's Komodo dragons (*Varanus komodoensis*). This warning has been extended to tour operators and boat owners, and if these individuals violate their licenses a second time, they will be permanently banned from operating in Komodo National Park.

These recent actions are in response to a video that went viral which showed several tour guides taking tourists to closely interacting with dragons from a boat, using a wooden stick to push back dragons as they swam toward the boat. Officials plan to release a guide map for tourists which will determine which areas of the park are open to the public and those that are prohibited.

Source: www.republika.co.id; 9 April 2018

Updated IUCN Red List Assessments for Varanids

The International Union for Conservation of Nature (IUCN) has just released updated Red List rankings for *Varanus mertensi* and *V. mitchelli*, elevating these species to Endangered and Critically Endanered, respectively. Due largely in part to the spread of the toxic, invasive cane toad (*Rhinella marina*) which now occurs across northern Australia, both *V. mertensi* and *V. mitchelli* have experienced widespread population declines and local extirpations. No recovery of populations of either species have been documented once cane toads have become established within their range.

The IUCN Red List is an internationally-recognized, comprehensive and objective approach to evaluating the conservation status and extinction risks of plant and animal species. Assessments are grounded in a scientifically rigorous approach, and prepared by a network of scientists and partner organizations that collectively hold what is likely the most comprehensive and up to date information on the biology and conservation status of a species. Red List assessments are updated as new information becomes available.

Sources:

Shea, G., J. Woinarski & H. Cogger. 2018. *Varanus mitchelli*. The IUCN Red List of Threatened Species 2018: e.T83778268A101752345.

Shea, G., J. Woinarski, S.M. Macdonald & H. Cogger. 2018. *Varanus mertensi*. The IUCN Red List of Threatened Species 2018: e.T83778246A101752340.

Report on the 2018 Jubilee Annual Meeting of the "AG Warane und Krustenechsen" of the DGHT

This year, the AG-Warane und Krustenechsen celebrated its 10th annual meeting. In total 49 attendees from Austria, the Netherlands, Switzerland and Germany met from 14 to 15 April 2018 at Frankfurt Zoo, which set an all-time attendance record for the working group since its re-establishment in 2008. Markus Monzel, President of the DGHT, and Vice President Alexander Meurer were in attendance as the guests of honor. Monzel welcomed all attendees on behalf of the DGHT.

Bernd Eidenmüller from Frankfurt began the program with his travel report, "*Yawning in the morning – A Visit to the last Dragons*" about a stay at Komodo National Park. In addition to his wife Uschi, he was accompanied by Paul Horner and Gunther Schmida from Australia, and filmmaker Markus Schmidtbauer, who had already visited Komodo dragons in the past for several TV productions. Aside from the park's famous monitor lizards, other typical faunal elements of the Lesser Sunda Islands such as *Cyrtodactylus darmandvillei* and *Trimeresurus insularis* were also discussed. For the latter snake species, Eidenmüller showed both morphotypes - the typical green and strikingly blue-colored variants. He expressed concern that the beautiful blue specimens have been decimated by the numerous tourists that visit the national park each year.

Next, André Koch (Bonn) reported on "*Unpublished Historical Illustrations of Monitor Lizards at the Naturalis Archive in Leiden*". Besides naturalistic portrayals of water monitor lizards (*Varanus salvator* ssp.), there was also a rather stylistic illustration of the holotype of the New Guinean emerald tree monitor (*Varanus prasinus*) belonging to the unpublished heritage of the Natural History Commission for Netherlands East Indies. Between 1820 and 1850, this commission had sent out young naturalists and artists in order to study and document the exotic fauna and flora of the East Indies, now Indonesia. Next to the Dutch Pieter van Oort (1804–1834), who produced a wealth of superb natural history illustrations, the Prussian Heinrich von Gaffron (1813–1880), amongst others, worked for the colonial rulers in Asia.

Julia Ulrich and Thilo Böck (both from Austria) then gave a detailed lecture about "*Natural and Safe Terrarium Facilities*". While Julia reported on her experiences as a veterinarian with the consequences of keeping mistakes such as severe burns, Thilo concentrated on the principles of lighting techniques and the safe installation of terrarium equipment for monitor lizards.

After a lunch break, Thomas Schaub (Kappel,

Attendees of the 2018 meeting of the "AG Warane und Krustenechsen" in Frankfurt, Germany.

Varanus komodoensis at Frankfurt Zoo, Germany.

Switzerland) continued with a talk about "*Burns in Monitor lizards*" caused by the incorrect use of strong spotlights. He explained how to avoid accidents and cure injuries, the treatment of which is often protracted.

Under the title "*Goin' around the Corner*" Dennis Fischer (Darmstadt) talked about his holiday trips to Australia. During two three-month long journeys, he was able to observe 87 out of about 950 Australian reptile species as well as some amphibians and other characteristic animals of Australia. His focus was on the nine monitor lizard species he encountered, such as *V. giganteus* and *V. rosenbergi*. In addition to sharing some excellent photos, video sequences were used to document the behaviour of these lizards. With special interest, Fischer studied the feeding ecology of the *V. gouldii* complex through the examination of road-killed specimens. Numerous fantastic nature and landscape photographs made his presentation a real enjoyment for the audience.

Afterwards, the general assembly of the working group took place. First, André Koch reported on some news about monitor lizards, and discussed newly described species and other varanid publications and projects, as well as activities of the IUCN Monitor Lizard Specialist Group and the International Varanid Interest Group. Following this, elections were held which resulted in a change in the leadership team of the working group. After eight years as the group's leader, Thomas Hörenberg did not wish to continue this position. Overwhelmingly, Thilo Böck was elected as the new head of the AG Warane und Krustenechsen. Dennis Fischer agreed to take on the role of treasurer, while André Koch was confirmed as scientific leader. On behalf of the working group, André Koch highlighted Thomas' longstanding engagement which was greatly acknowledged by the audience. Alexander Meurer kindly served as elections administrator.

The conference concluded with Thomas Würflein's (Demitz-Thumitz) talk, "*Monitor Lizards, Helodermas and Species Protection Laws*". Würflein, who works at the responsible department in Saxony, explained the legal regulations relevant for the keeping of monitor lizards in captivity. By referencing several online databases, he showed how private keepers can obtain information about the protection status of all monitor lizard species and *Heloderma*. The vivid discussion with the audience reflected the importance of purchasing specimens only with the right permissions and documents. Würflein also pointed to the compulsory registration for captive monitor lizards.

Discussions and conversations between the attendees were continued over dinner. On Sunday morning, attendees met again at the zoo for a guided tour by Johannes Köhler (Frankfurt Zoo). At the Grizmek House he talked about his experiences with caring for the zoo's two female Komodo dragons. Next, attendees visited the Exotarium, where *Varanus glauerti* and numerous other reptiles and amphibians are successfully kept and bred.

We thank all speakers as well as Dennis Fischer and Johannes Köhler, the local organizers, for a successful meeting at the Frankfurt Zoo.

\- *Thomas Hörenberg & André Koch*

New Book on Australian Monitor Lizards

Australian Monitors
Gunther Schmida
2017
English, Hardcover, 220 pp.
Self-published
ISBN: 9781389577772

Gunther Schmida has recently authored a new hardcover book entitled, *Australian Monitors: A Guide to the Amazing Monitor Lizards of Australia*. According to the book's description, "The book represent [sic] the most comprehensive treatment of this unique lizard family with 282 excellent images and informative text aimed at the general public, hopefully inspiring more interest and a love and better understanding of the environment".

The book is available for preview and purchase at: http://au.blurb.com/b/8199671-australian-monitors

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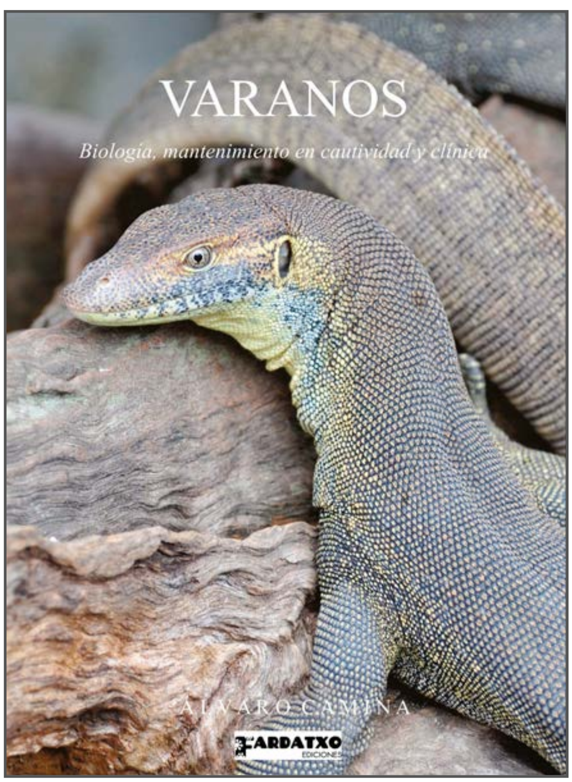
New Book on the Biology, Captive Maintenance, Breeding, and Medicine of Varanids



Varanos: biología, mantenimiento en cautividad y clínica
Álvaro Camina
2018
Spanish, Hardcover, 281 pp.
Fardatxo Ediciones
ISBN: 9788469782866

A new book in Spanish authored by herpetologist Alvaro Camina on the biology, captive maintenance and medicine of monitor lizards entitled "*Varanos: biología, mantenimiento en cautividad y clínica*" has been published by Fardatxo Ediciones. In this well documented, carefully written and wonderfully illustrated 281 page book, the author takes us on a journey across the mighty world of monitor lizards. His life-long interest and dedication to the study and captive maintenance of monitor lizards has resulted in a unique document, full of relevant information on both the natural world and captive husbandry of varanids. The book includes eight chapters and starts by exploring several aspects of the interesting biology of monitor lizards, including their complex taxonomy, distribution, habitat, diet and reproduction (both in the wild and in captivity) as a prelude to a detailed account of all recognized extant species. The species accounts are structured and presented by geographical area and habitat and include very nice photographs, well-documented distribution maps, and detailed information on the identification, distribution, habitat, and diet of monitor lizards, as well as unique information on their maintenance and behavior in captivity based on the literature and the personal experience of the author. The final chapter is an 82 page, well-illustrated account of the most common diseases of monitor lizards in captivity, including eight detailed clinical cases, contributed by three highly-skilled and experienced veterinarians.

Source: Salvador Carranza, Institut de Biologia Evolutiva (CSIC-UPF), Barcelona, Spain

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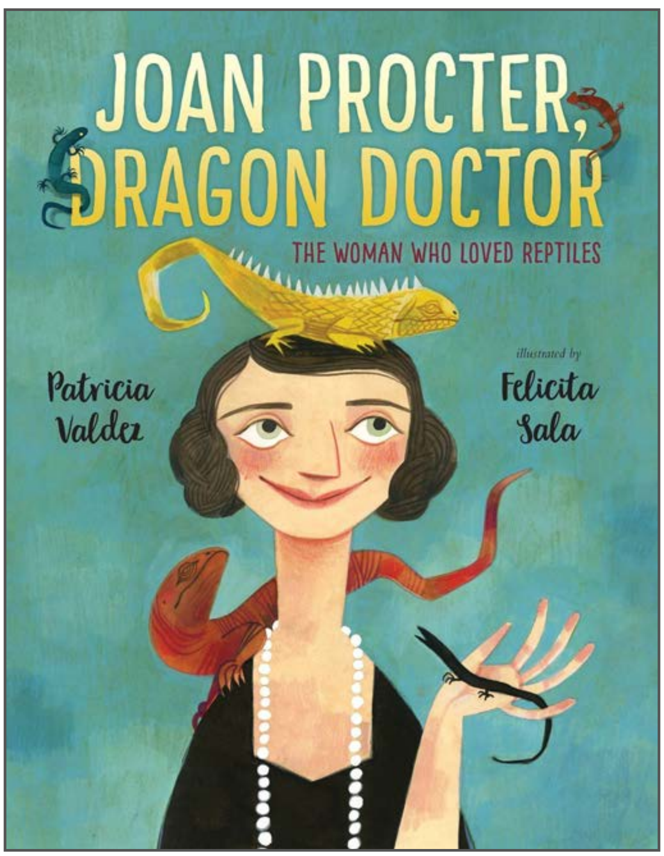
New Children's Book Celebrates the Life and Career of "Dragon Doctor" Joan B. Procter



Joan Procter, Dragon Doctor: The Woman who Loved Reptiles
Patricia Valdez & Felicita Sala
2018
English, Hardcover, 40 pp.
Alfred A. Knopf Publishers, New York
ISBN: 0399557253

Joan B. Procter served as curator of reptiles at the Zoological Society of London's London Zoo from 1923-1928, and was the zoo world's first female reptile curator. Although her career was cut short by a debilitating illness, Procter made many important contributions to the study of reptiles, particularly Komodo dragons, having overseen the care and medical management of two dragons that arrived at the London Zoo in 1927. Through this experience, she became the world's leading expert on Komodo dragons at the time.

A new children's picture book geared towards children aged 4-8 recounts the life and career of Procter through colorful illustrations depicting her important pioneering work as the world's first female reptile curator.

ARTICLES

Biawak, 12(1), pp. 12–22

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^2ha^{-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.

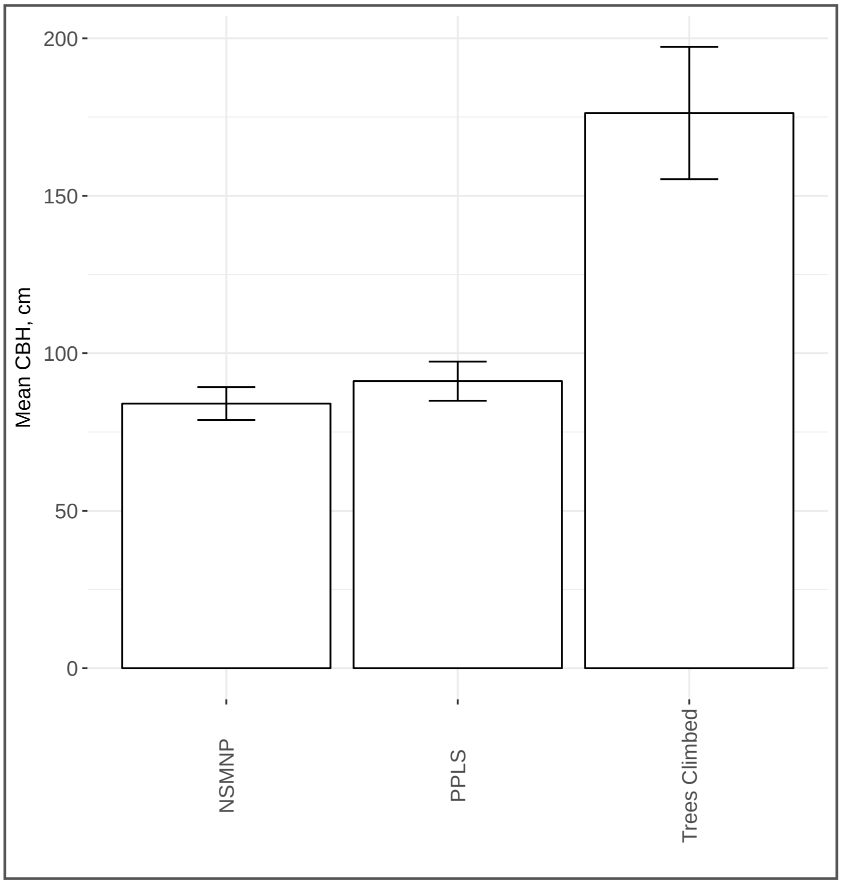

Fig. 2. Mean Circumference at Breast Height (CBH, in cm) with standard error bars of trees sampled in PCQM surveys in *Varanus bitatawa* habitat in the Northern Sierra Madre National Park (NSMNP) and the Peñablanca Protected Landscape and Seascape (PPLS) in northeast Luzon and the mean CBH of trees climbed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

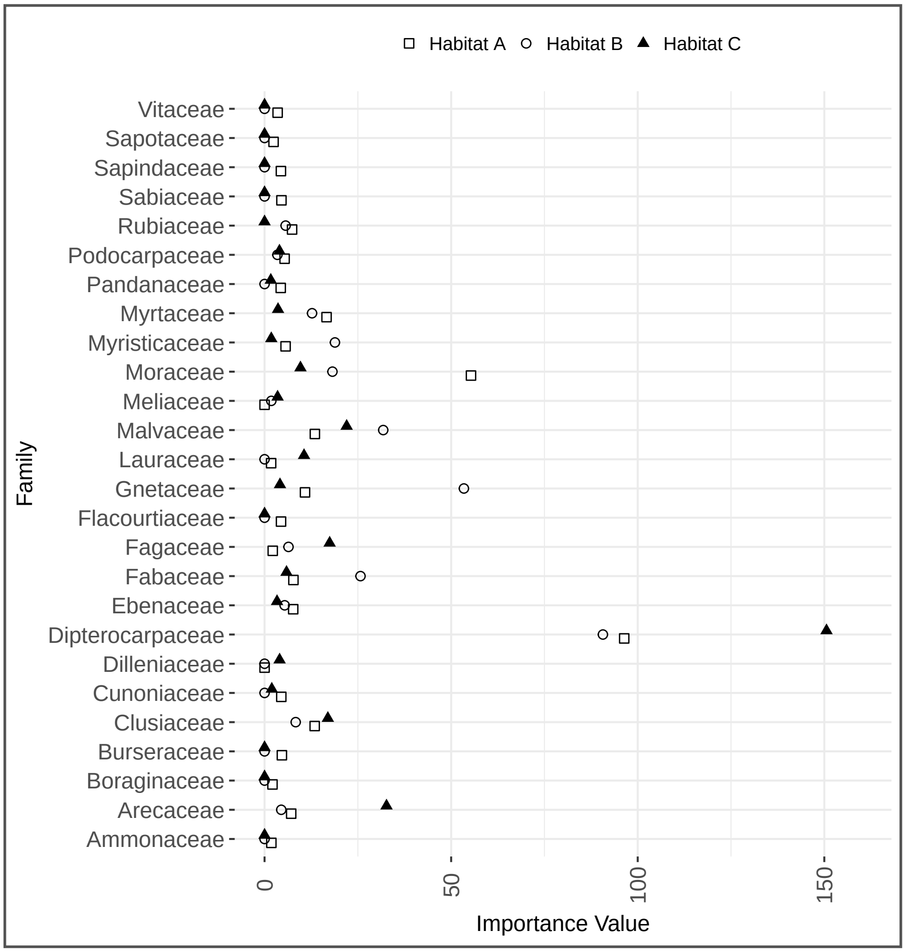

Fig. 3. Importance values for identified tree families in 3 three locations (A, B) within the Northern Sierra Madre National Park (NSMNP) and (C) in the Peñablanca Protected Landscape and Seascape (PPLS) in northeast Luzon where Varanus bitatawa were caught in 2013. Importance value = relative density + 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 (trees per ha^{-1})	Encounter Rate (trees per m^{-1})	Distance Model Parameters			95% CI		ESW (m)
				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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Relative Abundance and Risk Assessment of Lace Monitors (*Varanus varius*) on Fraser Island, Queensland: Are Monitors Habituated to Human Presence?

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Abstract - As the human population continues to increase throughout the world, more land is being converted into urban environments. This imposes significant pressures on wildlife living in modified landscapes, where some will be able to survive, and others will not. In order to determine whether the lace monitor (*Varanus varius*) can live in human modified landscapes, *V. varius* were observed in several natural and modified habitats on Fraser Island. Relative abundances and risk assessment were measured in areas of high and low human densities. Direct and tangential approaches were used to record flight initiation distances and investigate risk perception of the monitors. *Varanus varius* were observed more frequently in campsites where people were present than in natural habitat, but only up to a certain level of development. Monitors also perceived people as less of a threat inside campsites than in natural habitats where human presence was much lower. The direction of approach by the observer also led to different levels of risk assessment, with a direct approach perceived as more threatening. *Varanus varius* on Frasier Island seem to be able to thrive around the edges of human development, as long as some natural habitat is available, and are therefore classified as urban adapters.

Introduction

Anthropogenic activity is rapidly changing natural landscapes. One of the most important and rapidly occurring changes to landscapes is urbanization, where land is modified to create suitable environments for people to live in (Miller & Hobbs, 2002). This change in land use can have direct impacts on the organisms that live in and around affected areas. Some organisms, such as pigeons (*Columbia livia*) and brown rats (*Rattus norvegicus*) are able to thrive in city centers lacking natural habitats, and are known as urban exploiters (McKinney, 2006). Others, such as many of the large mammal and predatory bird species, cannot live near urban environments, and are known as urban avoiders. Urban exploiters become dependent upon urban resources, while urban avoiders are extremely sensitive to change and disappear quickly (McKinney, 2006).

Understanding which species will be able to survive urbanization has important conservation implications. A third category of organisms that are able to adapt and survive in human-altered landscapes are known as urban adapters. These species occur where elements of natural landscapes are still intact and where they can continue to use natural resources, but are also able to make use of anthropogenic food and shelter (McKinney, 2006). This category includes opportunistic mesopredators such as red foxes (*Vulpes vulpes*), coyotes (*Canis latrans*), and raccoons (*Procyon lotor*) that are able to thrive in and around urban environments, and sometimes achieve greater abundances than in natural landscapes (Bateman & Fleming, 2012).

Monitor lizards (*Varanus spp.*) are common native predators in Australia, and depending on the presence of larger predators such as the dingo (*Canis lupis dingo*), they can fill either the role of apex predator or mesopredator (Sutherland *et al*., 2011). The lace monitor (*V. varius*) is the second largest monitor lizard in Australia, and is distributed along much of the east coast (Shine, 1986), which also supports the highest human population density in the country. Therefore, it is inevitable that *V. varius* will come into contact with humans in modified landscapes throughout its range, where they may or may not be able to adapt to urbanization.

Varanus varius has a very broad and opportunistic diet, including arthropods, mammals, birds (including their eggs), and other reptiles (Guarino, 2001). It also commonly seeks out carrion, and has also been known to consume human garbage (Weavers, 1989). A previous study on another species of monitor lizard found that *V. salvator* occurred in significantly greater abundances around areas of human presence on Tinjil Island, Indonesia than in natural, un-modified landscapes. Although here human presence was only in the form of small campsites, *V. salvator* were attracted to human food refuse (Uyeda, 2009).

The introduction of a trophic subsidy to a landscape has the potential to alter the population dynamics of a species in an environment by adding non-natural resources. Jessop *et al.* (2012) studied the effects of human trophic subsidies in the form of human food refuse on population dynamics and morphological traits of *V. varius* in southeastern Australia and found that the overall abundance of *V. varius* was much higher around human food refuse sites than natural landscapes. Additionally, Jessop *et al.* (2012) found that *V. varius* reached much larger sizes in these altered environments, and that the population was male-biased. Although this study was not conducted near a large urban area, it does indicate that monitors are able to take advantage of human-mediated resources in the environment, which enables them to survive on the fringes of human settlement, and that this behavior influences morphology and population characteristics (Jessop *et al.* 2012).

Varanus varius are highly active lizards that maintain large home ranges exceeding 150 ha which tend to overlap with those of conspecifics (Guarino, 2002). If there is a location in an environment where conditions are more favorable for monitors, such as a site containing human food refuse, it is plausible that many individuals could congregate around the same area and have overlapping home ranges. Such reductions in home range sizes and tolerance of conspecifics are typical of urban adapters in areas with abundant food resources (Bateman & Fleming, 2012).

As *V. varius* seek out human trophic subsidies, an increase in the frequency of human-monitor interactions is expected. Monitor lizards have been hunted by Australian aboriginal people for thousands of years, and therefore perceive humans as predatory threats (Bird *et al.*, 2008). Optimal escape theory predicts that prey should flee from an approaching predator at the point when the risk of predation is equal to the cost of escape (Ydenberg & Dill, 1986). Several factors such as the speed and direction of approach by the predator, along with the direction of gaze can influence the level of risk represented by the predator, as well as escape decisions (Bateman & Fleming 2011, 2012, 2014; Stankowich & Blumstein, 2005). A common method of measuring how a prey animal perceives a predator as a risk is through flight initiation distances (FID), which is the distance between a prey animal and predator when the prey begins to flee (Ydenberg & Dill, 1986). It can be a useful metric as it is easy to collect, is repeatable, and variables influencing FID can be easily manipulated; however, when an animal is living in an urban environment with humans present, it can become exposed to a range of different stimuli from potential predators. In order to become successful, urban adapters and exploiters must be able to distinguish between legitimately threatening stimuli and non-threating stimuli. This distinction inevitably leads to human habituation, since humans are a common stimulus in urban environments (Bateman & Fleming, 2014). A study conducted on black-girdled lizards (*Cordylus niger*) in South Africa found that FID was significantly shorter when subjects were exposed to human presence than when people passed by infrequently (Cooper & Whiting, 2007). This shorter FID is a result of the lizards becoming habituated to the presence of humans and perceiving them as less of a threat. Therefore, as *V. varius* encounter more humans by seeking out human trophic subsidies, it can be predicted that they will become habituated to the presence of people and perceive them as less of a threat.

This study seeks to determine how the abundance of *V. varius* changes in areas of differing human densities, and to observe how *V. varius* perceive humans as a threat on Fraser Island, Queensland. Due to the added level of protection around campsites and the possibility of gaining trophic subsidies, it is predicted that *V. varius* occur in greater abundances in campsites than on the trails. To determine how *V. varius* perceive people as risks, their FID was measured inside and outside campsites, and a direct and tangential approach towards the animal was implemented to observe how FID changed with a predator's (*i.e.*, the observer's) direction of approach. Conversely, in areas of greater human density, *V. varius* is expected to have a much lower FID than in areas of low human density, which would be an indicator of habituation to human presence.

Methods

Study Sites

Fraser Island, located off the southern coast of Queensland, is the world's largest sand island, and attracts over 360,000 tourists a year. This UNESCO World Heritage Area is also a part of the Great Sandy National Park, and supports a vast array of forest types and wildlife (Department of Environment and Resource Management, 2008). The island is known for its dingo (*Canis lupis dingo*) population, which is a primary attraction for tourists visiting the island (Thompson *et al*., 2006). This abundance of wildlife and tourists has led to many interactions between these groups. Unfortunately, in 2001 a nine year-old boy was attacked by a pack of dingoes, which prompted some landscape changes on the island. In order to minimize negative interactions between humans and dingoes, the park service works to educate tourists, and has also erected dingo fences around all campsites and popular tourist destinations (Georgette & Howard, 2003). Typically, these wire fences are approximately 1.5 m tall, and have large square openings between the wires measuring approximately 15 cm wide, though the specific style of fencing is not uniform throughout the island. During the summer months when they are much more active, *V. varius* make up a large portion of the dingo's natural diet (Angel-E., 2006). Since monitors are able to slip through the gaps in dingo fences, campsites enclosed by fences also offer a degree of protection from the island's apex predator. The combination of added protection from dingo fences with the possibility of human trophic subsidies is expected to result in much higher abundance of *V. varius* near areas of human settlement on Fraser Island.

Surveys were conducted between 12-27 April 2015 on sunny days when *V. varius* would be expected to be active (Booker & Wombey, 1986). To measure the difference in monitor abundance and risk assessment between areas of high and low human densities, all high human density areas were located in campsites that the Queensland Park and Wildlife Service enclosed with dingo fences, while low human density areas did not have any fencing. Four different locations were selected within dingo fences to represent high human density areas (see Fig. 1).

1. Dilli Village Environmental Camp run by the University of Sunshine Coast (25º 36′ 0.36″ S; 153º 5′ 31.56″ E). Both students from the university and tourists use the facilities at this campsite. At Dilli Village, a 355 m transect along the edge of the campsite, along with a 100 m transect through the middle of the campgrounds were surveyed.

2. Lake Boomanjin (25º 33′ 24.12″ S; 153º 3′ 55.1″ E). This site used to be a popular campsite, but since the lake flooded several years ago, many tourists have dismissed it as a good camping location (Anonymous, pers. comm.). Although not many people camp here overnight, the site has become a popular picnic lunch spot. This campsite was rectangular in shape, measuring 1,736 m^2, and was easily observed.

3. Central Station (25º 28′ 40.8″ S; 153º 3′ 41.4″ E). This campsite is located in the center of the island and is considered a very popular camping destination. It is set among some of the island's largest forests and also supports a large abundance of wildlife. Central Station consists of two different campsites; the Kauri site and Satinay site. Transect surveys were conducted along the roads in each campsite with the Kauri transect measuring 430 m, and the Satinay transect measuring 500 m in length.

4. Eurong Village (25º 30′ 41.4″ S; 153º 7′ 14.5″ E). This large area supports the Eurong Beach Resort and several residential homes. Many tour companies travel to Eurong during the day for tours and lunch. Two transects were surveyed in Eurong; one around the resort (895 m in length), and one around Second Valley (600 m in length), where locals live along with rental houses.

Since traffic on Frasier Island is limited to large trucks, the hiking trails remain relatively empty. To measure *V. varius* abundance and risk assessment in low human density areas, two trails were hiked through the middle of the island, which covered a total of 14.6 km. The first hike (Trail 1) was from Central Station to Lake Benaroon and measured 6.9 km. The second hike (Trail 2) was from Central Station to Lake McKenzie and measured 7.7 km. Each trail was hiked twice. Due to inclement weather, Dilli Village and Eurong were sampled over two days, whereas all other campsites were sampled over three full days.

Measuring abundance

At campsites enclosed by dingo fencing, transects

Fig. 1. Topographical map of central Fraser Island depicting the study area. Red circles represent campsites surveyed, and black lines represent the trails surveyed. The trails hiked were part of the Fraser Island Great Walk.

were conducted at least 10 m away from the fence. Transects were scanned to approximately 10 m on either side of the observer. Each time the observer walked around a campsite, the number of paces to complete a transect were counted. The paces were then averaged for each replicate, and then converted into meters (116 paces = 100 m) to find the total length of the transect. In campsites, transect surveys were conducted three times a day, based on established activity periods of *V. varius* (Seebacher & Grigg, 2001): 0800-0900 h, 1200-1300 h, and 1500-1600 h. This led to a total of nine replications at each site at differing times of the day. Along trails outside the dingo fences, each side of the trail was scanned about 5 m into the bush for the entire length of the transect. All hikes were conducted between the hours of 1000 and 1500 h.

Monitors that were spotted were classified as adult (> 1.5 m total length [TL]), sub-adult (1.0–1.4 m TL), or juvenile (< 1.0 m TL) based on visual approximations. The distance from the observer and the distance to cover (*i.e.*, a large tree or thick vegetation) were estimated for each individual. The distance of the monitor from the observer was also assumed to be the alert distance. Along with recording monitor abundance, data on the number of people present in each campsite, or encountered along each trail were also recorded, categorizing what they were doing as inactive, active, or eating.

Measuring risk assessment

When a monitor was spotted, two different approaches were implemented. The first was a direct approach towards the lizard at a slow pace of approximately 1–2 km/hr. This direct approach would eventually force the monitor to flee for cover. The second approach was a tangential approach, where the observer walked past a monitor at a minimum bypass distance of 3 m at the same pace. This minimum bypass distance was established based on tourists' experiences with encountering monitors on the island. This technique was used because risk assessment decreases as minimum bypass distance increases, so *V. varius* may not always flee. Once a monitor was spotted, it was approached by either of these approaches, alternating approaches.

Table 1. Summary of *Varanus varius* observations at each location. Relative abundance assumes that each observation represented a different individual. Abbreviations used: A = adults; S = subadults; J = juveniles).

Location	Transect Length (km)	No. Replicates	No. Observations (Total [A.S.J])	Relative Abundance (Individuals/km)
Dili Village	0.455	6	19 [11.8.0]	41.7
Lake Boomajin	0.1736	9	5 [0.5.0]	28.8
Central Station	0.93	9	20 [5.13.2]	21.5
Eurong Beach Resort	0.895	6	0	0
Eurong- 2nd valley	0.6	6	2 [2.0.0]	3.3
Trail 1	34.5	2	2 [0.0.2]	0.06
Trail 2	38.5	2	0	0

Sometimes the area where the animal was spotted would not allow a tangential approach due to some kind of obstruction such as vegetation or a truck. In order to record FID, the distance between the lizard and the observer when it began to flee to cover was measured. The typical flight response for *V. varius* is to run away from a predator and climb up a tree, or hide under a log or in thick vegetation for cover. To accurately measure this distance, a tape-flagged pencil was dropped when the monitor fled, and the distance from it to the point of cover was measured. Monitors that did not flee from a tangential approach were recorded with a FID of zero meters.

Results

Abundance

A total of 48 *V. varius* observations were recorded over the course of this study; 46 were in fenced campsites, and only two were made on trails (see Table 1). All monitors observed within campsites were recorded as adults or sub-adults (Fig. 2), with only two juveniles observed at Central Station. Both observations on trails were of juveniles. Central Station had the most observations, with 20 observations recorded over three days. Dilli Village had the highest relative abundance, with around 42 observations per km, followed by Lake Boomanjin with 29 observations per km. Eurong had the lowest relative abundance of monitors, with none observed by the resort, and only two observed in Second Valley. While there were a total of two observations in both Eurong and both trails, the trails covered a much greater distance, leading to a lower relative abundance. Since none of the monitors were photographed or captured to identify individuals, it cannot be determined if these observations were independent of one another, and it must be assumed that the chances of counting individual monitors twice or more were the same at all locations, leading to a relative measure of abundance.

Fig. 2. The typical flight response for *V. varius* is to flee for cover up a tree, as seen here near a family campsite in Dilli Village

The number of observations recorded in each location differed, along with the number of people encountered at each location (see Fig. 3). Eurong Beach Resort had the highest average number of people observed per day (31 people), although there were many more people observed on average (54 people) during noon transect surveys. Similarly, the average number of people observed at Lake Boomanjin was greatest during noon transect surveys (4 people) as opposed to morning (0 people) and afternoon (2 people) surveys. This increase in the average number of people observed during noon transects is influenced by the popularity of Lake Boomanjin and Eurong Beach Resort as lunch destinations. Conversely, the average numbers of people observed in Dilli Village and Central Station were greater in the morning (18 and 13 people, respectively), than noon (7 and 1, respectively) or afternoon (8 and 2, respectively) surveys. In both of these popular camping locations, people were present in the morning, but later ventured away from the campsite to explore the island.

Monitors were much more likely to be found during morning and noon transect surveys than afternoon surveys. The greatest number of monitor observations recorded at Central Station was during noon surveys, which was the same time as the lowest average number of people recorded at this location (1 person). Similarly, at Lake Boomanjin, the highest numbers of monitor observations were recorded when the campsite saw the lowest number of people, during the morning and afternoon surveys. No monitors were recorded at Eurong Beach Resort, which also supported the largest average number of people; only two people were recorded on the trails. The behavior of people in campsites did not appear to influence monitor abundance or behaviors.

Flight initiation distances

Flight initiation distance was measured for each *V. varius* observed. There were a total of 26 direct and 20 tangential approaches made in campsites, and only one of each approach on the trails. FIDs, for both direct and tangential approaches, were lower in all campsites than on trails (see Fig. 4). An individual observed at Eurong had the shortest FID, where a tangential approach did not cause the monitor to flee, and a direct approach revealed a FID of 1.8 m. At Lake Boomanjin, direct approaches resulted in an average of 4.1 m (n = 2), and tangential approaches resulted in an average of 2.7 m (n = 1). Central Station and Dilli Village yielded very similar results. The average FID on direct approaches at Dilli Village was 5.8 m (n = 11), and 5.5 m (n = 11) at Central Station. Tangential approaches yielded fairly similar results between locations, where the average FID for tangential approaches at Central Station was 4.9 m (n = 4), and 4.3 m (n = 4) at Dilli Village. Out on Trail 1, a direct approach yielded a FID that was much

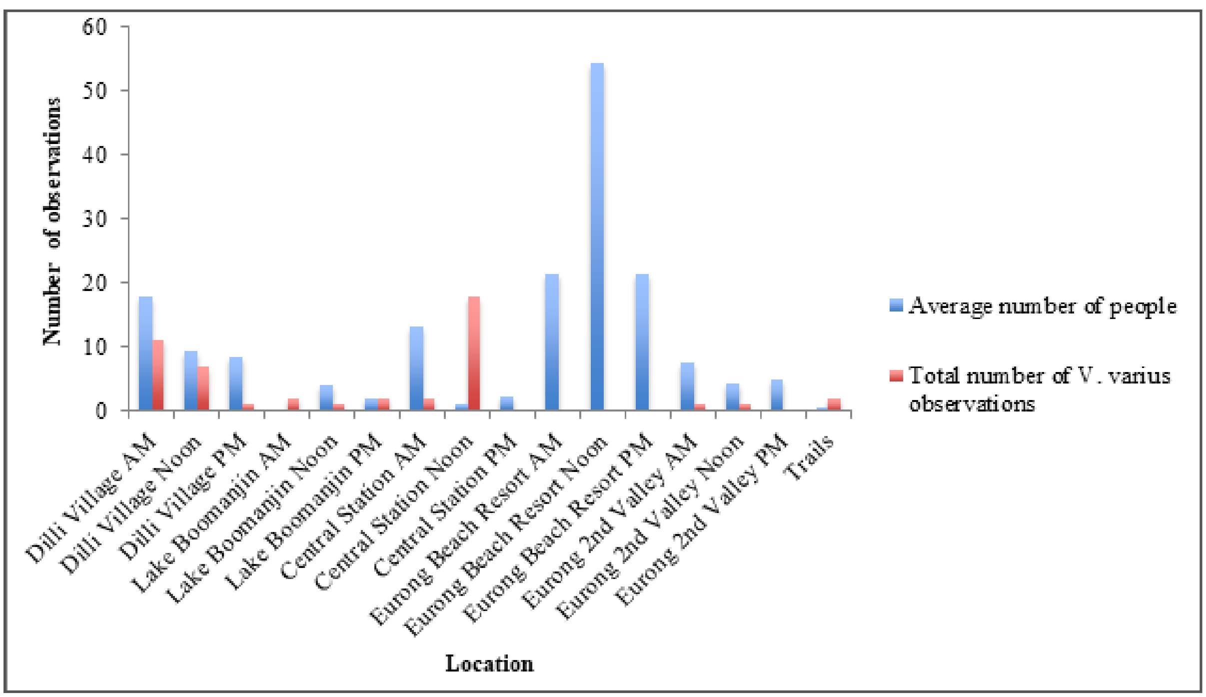

Fig.. 3. Average number of people and total number of *V. varius* observations made in each location. Trails 1 and 2 have been combined.

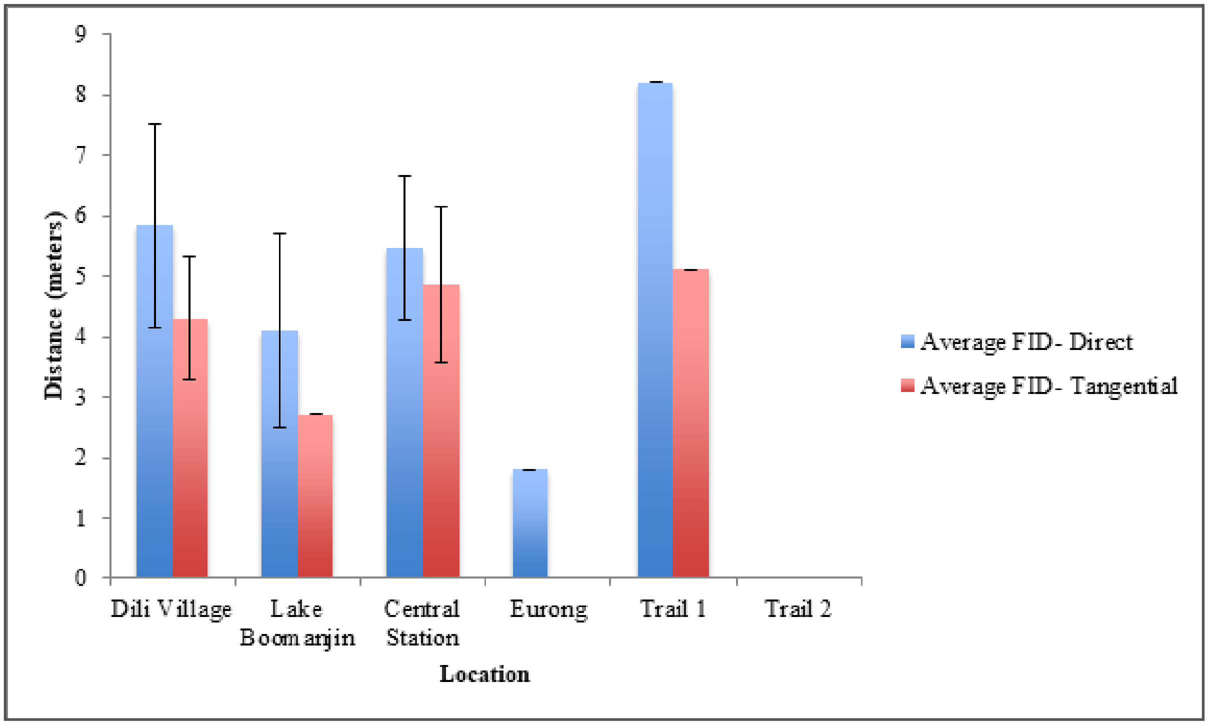

Fig..4. Average FID of both approaches in all locations with standard error bars. (Eurong Beach Resort and Second Valley have been condensed to just Eurong since no monitors were recorded in Eurong Beach Resort).

larger than the average at any campsite, at 8.2 m (n = 1); whereas the FID for a tangential approach was also higher at 5.1 m (n = 1). No monitors were recorded on Trail 2, so FID could not be measured.

Of the 20 *V. varius* that were tangentially approached, 55% (n = 11) of them did not flee (see Fig. 5). At Second Valley in Eurong, the only monitor tangentially approached did not flee. Two out of three monitors at Lake Boomanjin did not flee from a tangential approach; whereas 56% (n = 9) of individuals in Central Station, and 43% (n = 7) of individuals at Dilli Village did not flee. All *V. varius* fled while out on the trail. When a monitor did not flee, it generally moved slowly away from the observer, while still watching the observer's actions. On several occasions inside campsites, a monitor was tangentially approached while they were eating and they failed to leave their food source. In other times they seemed indifferent to the observer's presence, and would not move at all.

Discussion

Abundance and behavior

From the data collected, it appears that *V. varius* preferentially inhabits campsites. Although the dingo fence adds a large degree of protection from predators, there may be a limit to how much human presence they can tolerate. No *V. varius* were observed in the Eurong Beach Resort, although two individuals were recorded in Second Valley. The resort represents a highly developed area on the island with a large number of people and buildings and little natural habitat remaining; however, the absence of recorded observations in this study does not completely rule out *V. varius* from inhabiting this location. Second Valley is separated from Eurong Beach Resort by a sand dune, and is surrounded by dense native vegetation, along with non-native plants planted by homeowners which offer a greater degree of cover than Eurong Beach Resort within the same dingo fence. The locations with the greatest number of *V. varius* observations (Dilli Village and Central Station) represent human-modified landscapes that still retain many natural elements as well. Although Dilli Village had several buildings such as bunk houses and restrooms, it is surrounded by a natural environment and has relatively few human visitors. Central Station was surrounded by a large and dense forest, which provided plenty of cover options for the monitors. Many more observations were made inside campsites than outside them. Though the trail represents the unmodified natural environment in which *V. varius* would inhabit, campsites

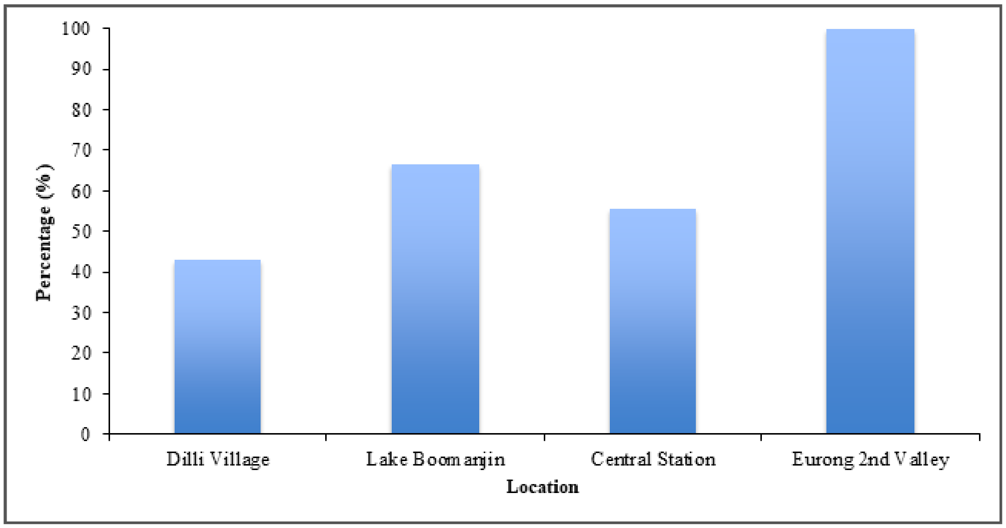

Fig. 5. Percentages of *V. varius* at each location that did not flee from a tangential approach.

provide protection from dingoes, and also offer a human mediated trophic subsidy.

Inside campgrounds, *V. varius* were often observed searching for food remains. Frequently while conducting transect surveys, monitors were found eating small food scraps left on the ground and were even seen tearing open a trash bag in Dilli Village. Although Fraser Island management encourages people to always keep their food sealed and stored away, multiple instances of people blatantly leaving food or food refuse out in the open were observed, which will inevitably attract *V. varius* to campsites. Previous work has found that *V. varius* in areas with human trophic subsidies have decreased numbers of enzymes that infer metabolic syndromes, decreased plasma corticosterone (a marker of stress) and decreased blood parasites (Jessop *et al.*, 2012). Although no blood samples were collected during this study, it is likely that the *V. varius* on Fraser Island may have similar physiological markers due to their consumption of human trophic subsidies.

A study on *V. salvator* in Indonesia found that the lizards had become conditioned to the arrival of food refuse (Uyeda, 2009). When the regular 0600 h dumping of food scraps stopped, *V. salvator* still arrived at that time to search for food (Uyeda, 2009). At Central Station, almost all observations were recorded during noon transects, but a few were made in the morning. Although the people observed in Central Station did not all leave at the same time, almost everyone had departed by noon. It seems that the monitors in this location have become conditioned to the daily departure of tourists as an opportunity to forage. Similar behavior was also observed at Lake Boomanjin, where only one *V. varius* observation was recorded around noon, when most people were at the campsite. The highest number of *V. varius* observations at this site occurred during the morning and afternoon, when the least amount of people were present. These observations suggest that *V. varius* try to avoid interactions with people since they are perceived as a threat, but still view humans as a potential source for food. Since there were so many people at the Eurong Beach Resort, along with plenty of inaccessible garbage cans, there may not be much of an incentive for monitors to venture towards the resort, when they still have access to the same degree of protection in Second Valley.

The body sizes recorded within campsites are consistent with a previous study that looked at *V. varius* around human trophic subsidies (Jessop *et al.*, 2012). In the present study, the vast majority of recorded individuals were classed as an adult or sub-adult (*i.e.*, > 1 m TL). This aggregation of larger monitors has the potential to lead to competition and the exclusion of smaller individuals. It has been recorded that monitor lizards will kill and cannibalize smaller conspecifics when space is limited (Auffenberg, 1994; Johnston, 2008). While at Central Station, a dead juvenile *V. varius* was observed within the dingo fence; however, a cause of death could not be determined. Central Station was the only campsite where any juvenile *V. varius* were observed, and this could be attributed to the greater degree of cover available, along with trophic subsidies.

Special case of Lake Boomanjin

Upon arrival at Lake Boomanjin, it was initially believed that observations could not be collected from this specific campsite. At all of the other campsites, the dingo fences were constructed of wiring along posts with large square gaps measuring approximately 15 cm wide that allowed large adult *V. varius* to pass through. However, at Lake Boomanjin, the fence was of a different construction, and had small diamond-shaped openings measuring approximately 8 cm wide. Although adult animals could not fit through this fence, smaller sub-adults were still able to squeeze through. It is reasonable to believe that as highly skilled climbers, adult *V. varius* could be capable of climbing over the fence; however, this was not observed during this study. Lake Boomanjin also differed from all of the other campsites visited in that there were no overnight visitors except for the author on two out of three nights. In contrast to Central Station and Dilli Village where people left to explore the island during the day, few people were present in the morning or afternoon at Lake Boomanjin, and people only came to see the lake briefly or have a picnic around lunchtime. Since people still visited the campsite to eat food, they often left food refuse on the ground. These scraps were enough to attract *V. varius* that were small enough to squeeze through the smaller openings in the fence. There was never more than one *V. varius* observed at the same time within the campsite, and because no methods were used to identify specific individuals, there is no way of knowing if it was the same individual each time.

The *V. varius* of Lake Boomanjin had the second lowest FID in both approaches, and also had the second highest percentage of individuals not fleeing from a tangential approach. Eurong had the highest percentage of *V. varius* that did not flee from a tangential approach, where only one monitor's FID was measured with this approach. Since Lake Boomanjin had very low FID in both approaches, and a high percentage of *V. varius* that did not flee from a tangential approach, it can be inferred that the monitors at this campsite were highly habituated to the presence of humans. Although the campsite offers a human-mediated trophic subsidy to *V. varius*, the sub-adult monitors encountered were observed slipping through the fence back to natural cover after foraging.

Eventually, these small sub-adults will mature into large lizards that cannot fit through the smaller gaps in the Lake Boomanjin fence. Since they learned to forage for human food refuse within campsites, they may still rely on this refuse as a food source as they mature and grow older. Combined with their high habituation to people, adult *V. varius* accustomed to foraging for human food refuse may disperse to other campsites across Frasier Island. The Lake Boomanjin campsite could potentially serve as a location where young *V. varius* become habituated to people and conditioned to their food refuse, while still being protected from potential predators like the dingoes and larger *V. varius*.

Improvements for future study

Several shortcomings of this study must be addressed. One major issue was the timing of the study. *Varanus varius* are considerably more active during the summer months than winter months, and April is typically when some *V. varius* become inactive due to cooler temperatures (Guarino, 2002). This activity level in *V. varius* is represented in dingoes' diets, since their diet shifts away from *V. varius* during winter months, because the lizards are much less active. (Angel-E., 2006). Although *V. varius* were still active on the island in the present study, they may not have been foraging over larger distances, which could partially explain the low numbers of observations out on the trails. Additionally, the shorter scanning distance and the thickness of vegetation on the trails may have obscured potential observations. Temperatures during the day also were progressively cooling while data was collected on the island, which led to particularly cold days (*i.e.*, 15–20 °C) when *V. varius* would not be active. This cold weather precluded data collection for two days in the campsites, and three days on the trails. To resolve these issues, conducting this study during the warm summer months of October through March would be ideal. Additionally, having a longer timespan to collect data would allow researchers to wait out any inclement weather and resume surveys when *V. varius* is most active.

Another limitation to this study was that there were no methods introduced to identify and distinguish between individual monitors. This could have been accomplished either by photographing each individual's unique pattern or potentially by capturing and marking individuals. However, capturing the monitors may have the potential to influence their fear perception and flight behavior. Due to the inability to differentiate individual lizards, measures of abundance must be viewed in relative terms since it is assumed that chances of counting individual monitors multiple times were the same at all locations.

Ultimately, this study should be viewed as a pilot study. It was not possible to collect a robust dataset to yield sufficient statistical power across the very large island, but enough data was collected where a descriptive general trend could be recognized. *Varanus varius* were clearly more abundant in campsites than on trails, they were observed actively searching for food in campsites, and they frequently encountered humans. In order to conserve energy by not fleeing constantly, they should eventually habituate to humans (Bateman & Fleming, 2014). Although the data collected in low human density areas could not be replicated to the same level as in high human density areas, it appears that *V. varius* is able to habituate to human presence.

Conclusions

From the observations and data collected, it is clear that *V. varius* on Fraser Island seek out human food refuse as part of their opportunistic diet, and have consequentially become habituated to the presence of humans. The dingo fences surrounding campsites also provide an important source of protection from the monitors' main predator on the island, which may be another incentive to inhabit campsites. It appears that *V. varius* will be able to persist alongside human settlement on the island, but only up to a point. The Eurong Beach Resort may represent the upper limit of an environment that *V. varius* can live in due to the high density of people with little available human food refuse. If the island was to continue being developed, and more establishments like the Eurong Beach Resort are created, this could lead to a decrease in the *V. varius* population. However, due to Fraser Island's UNESCO World Heritage title and protection as part of the Great Sandy National Park, extensive development is unlikely.

In a global perspective, more and more land is being transformed through urbanization (Miller & Hobbs, 2002). Some species will be able to adapt to the changing landscape, while others will perish or avoid such landscapes. Based on these preliminary findings on Fraser Island, it is believed that *V. varius* is an urban adapter, since it can still persist in the presence of humans and gain some resources from them such as food, but still rely on natural elements such as trees and vegetation for cover. *Varanus varius* may be successful on the fringes of cities as long as some aspects of the natural landscape remain intact.

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Varanus bengalensis Predation by *Ophiophagus hannah* in Rajaji Tiger Reserve, India

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Abstract: In 2017, an adult *Ophiophagus hannah* was observed preying upon an adult *Varanus bengalensis* in Rajaji Tiger Reserve, northern India. Upon its capture, the snake took about 7–8 minutes to render the monitor unconscious, and another 20 minutes to swallow half of the monitor before disappearing with the lizard in the bush. Although a few records of *V. bengalensis* predation by *O. hannah* exist, this account constitutes the first record of this occurrence in Rajaji Tiger Reserve.

The king cobra *Ophiophagus hannah* (Cantor, 1836) (Serpentes: Elapidae) is the largest species of venomous snake in the world and has a broad distribution across India, Nepal, Bangladesh, Bhutan, Myanmar, and most of Southeast Asia (David & Vogel, 1996; Stuart *et al*., 2012). In India, it is distributed in the Western Ghats, the Shivalik and Terai regions of Uttarakhand and Uttar Pradesh, Bihar, Odisha, West Bengal, and the Andaman Islands (Whitaker & Captain, 2004). *Ophiophagus hannah* is known to feed primarily on snakes including their own species, and the only other prey items reliably reported from the wild have been two species of monitor lizard: the common Indian monitor (*Varanus bengalensis*) and the water monitor (*V. salvator*) (Bhaisare *et al*., 2010).

Varanus bengalensis (Daudin, 1802) occurs from southeastern Iran through south-central Asia (ranging from Afghanistan in the north as far south as Sri Lanka), and eastwards throughout Southeast Asia as far as Java and the Anambas Islands in Indonesia (Papenfuss *et al*., 2010). In India, this monitor is distributed in tropical and subtropical regions of the sates of Assam, Himachal Pradesh, Madhya Pradesh, Tamil Nadu, Gujarat, Mizoram, Maharashtra and Kerala where it occurs in almost all biotopes from evergreen forests to dry grasslands (Soni & Jarulla, 2010). It is one of the largest reptile species in southern Asia, but has several natural predators. In a recent study carried out in Sri Lanka, 24 species of animals including mammals, birds and reptiles were recorded as predators of *V. bengalensis* (Karunarathna *et al*., 2017).

Rajaji Tiger Reserve (29° 50′ – 30° 10′ N; 77° 50′ – 78° 30′ E, elevation 250-1100 m) is a crucial wildlife habitat in the Shivalik landscape, forming the north-western limit of the range of Asian elephants, tigers, great pied hornbills and king cobras in the Indian subcontinent. It falls within the Gangetic Plains biogeographic zone and upper Gangetic Plains province (Rodgers *et al*., 2002), and a major portion of this area is dominated by tropical moist deciduous forest.

On 8 June 2017 (0845 h), we observed an adult *O. hannah* preying upon an adult *V. bengalensis* in Mundal forest of the Rajaji Tiger Reserve (29° 56′ 29.8″ N; 78° 16′ 28.1″ E, 382.7 m; Fig. 1). While studying the behavior and ecology of Asian elephants in the area, an adult *V. bengalensis* (~ 120 cm in total length [TL]) was seen lying in a pool of rain-water on a rough forest road. Following the rustling of some dry grasses near where the monitor was lying, we observed that a large (~3.0 m TL) *O. hannah* of unknown sex had captured the monitor. The snake held the head of the monitor with its jaws for about 7–8 minutes until the monitor stopped resisting and became unconscious, when it then started to swallow it. At the same time, the snake was also attempting to drag the monitor into the grass from which it had originally emerged. It took the *O. hannah* approximately 20 min to swallow half of the monitor, before it retreated to the grass patch with the monitor

Fig. 1. *Ophiophagus hannah* preying on *Varanus bengalensis* in Rajaji Tiger Reserve, India. Photographed by **Ritesh Joshi**.

and disappeared. Since the observed case of predation, two specimens of *O. hannah* have been observed in this area. In 2013, Indian wildlife photographers filmed and photographed an *O. hannah* consuming a *V. bengalensis* (Tankha, 2013).

Some of the plant species recorded from the site include *Cynodon dactylon* (Bermuda grass), *Saccharum munja* (sarkanda), *Ficus benghalensis* (Indian banayan), *Aegle marmelos* (wood apple), *Mallotus philippensis* (kamala) and *Lantana camara* (lantana).

Varanus bengalensis is listed under Schedule I of the Indian Wildlife (Protection) Act of 1972 (Anonymous, 2003), CITES Appendix I (CITES, 2017), and as Least Concern in the IUCN Red List of Threatened Species (Papenfuss *et al*., 2010). Increasing development and anthropogenic activities across the riparian corridors of the Ganges, shrinkage of natural water sources inside protected areas, expansion of the road network across a long chain of protected habitats, and lack of awareness among the local people regarding the species' ecological role include some of the threats observed in the study area.

Although only a few records of *V. bengalensis* predation by *O. hannah* exist (Whitaker & Captain, 2004; Tankha, 2013), this account constitutes the first record of such predation in Rajaji Tiger Reserve, which forms an important repository of diverse fauna and is home to several species of threatened herpetofauna. Long-term scientific studies are needed to map the distribution of both *V. bengalensis* and *O. hannah* in different ecosystems within the State.

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Varanus flavescens: Status, Distribution and Potential Threats – A Case from Nepal

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Abstract - *Varanus flavescens* is the least studied varanid lizard of Nepal, and scientific information about this species is very limited. This study explored the status, abundance and existing threats of *V. flavescens* around the Jagdishpur Reservoir of Nepal through field work and questionnaire surveys. A population estimate survey was conducted along transect lines and a distribution map was prepared based on both direct observations of the species and indirect evidence of its presence. The study found that grass cover within swampy areas and along stream beds are the preferred habitats of this species. The major cause of population decline for *V. flavescens* in the study area is illegal hunting.

Introduction

Varanus flavescens, the yellow or golden monitor lizard, is a carnivorous poikilothermic reptile (Shah & Tiwari, 2004; Ghimire & Shah, 2014) that occurs in Bangladesh, India, Nepal, and Pakistan (Auffenberg, 1989; World Conservation Monitoring Centre, 1996). In Nepal, it is known as "*Sun Gohoro*" in the Nepali language, and is most active during wetter months of the year.

Varanus flavescens is listed in Appendix I of the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES), but it is listed as a species of least concern by the IUCN Red List (World Conservation Monitoring Centre, 1996). In Nepal, *V. flavescens* is found in 25 districts (Shah & Tiwari, 2004), and is protected by the National Parks and Wildlife Conservation Act of 1973 (GoN, 1973). The Department of National Parks and Wildlife Conservation (DNPWC) is the only government agency in Nepal which works for the conservation and management of wildlife. The DNPWC focuses its conservation programs in protected areas only. Human activities such as poaching and nuisance killing present challenges for the conservation of *V. flavescens* (Khatiwada & Ghimire, 2009). Although *V. flavescens* tend to have a large home ranges (Perry & Garland, 2002), their habitat is being encroached by humans for cultivation (Karki & Bista, 2008), and are therefore limited to small patches of habitat in Nepal.

In an effort to help fill in information gaps for the species in Nepal, this study investigated the distribution, current status and threats of *V. flavescens* in Jagdishpur Reservoir - a Ramsar Site, and its surroundings. This information will be useful for the species' effective conservation and protection in Nepal.

Materials and methods

Study Area

The study was conducted around the Jagdishpur Reservoir, Niglihawa Village Development Committee (VDC), Kapilvastu District of Nepal which was declared a Ramsar Site in 2003 (CSUWN, 2013) and is situated in the tropical region of Central Nepal. Wetlands are surrounded by cultivated land and a few smaller lakes. This area experiences a tropical monsoon climate of hot, rainy summers and cool, dry winters (Baral, 2008). Twenty species of fishes and 42 species of birds including 13 species of waterfowl have been recorded in the Reservoir (CSUWN, 2013). Several reptile and amphibian species including *Varanus bengalensis, V. flavescens, Python molurus, Sphaerotheca maskeyi,* and *Microhyla ornata* were recorded in this area during this study.

Population Surveys

Transect survey - Transect surveys were conducted to determine the population status of *V. flavescens* in the study area. A total of 73 transects (100 x 15 m) were walked, maintaining a 100 m gap between each transect. For each observation the number of individuals, body size, and age class (juveniles < 1 m in total length [TL]; adults >1 m TL) (Heyer, 1994; Sung *et al*., 2011) were recorded. Data from transect surveys were collected in two shifts: early morning (1000 to 1300 h) and late afternoon (1400 to 1800 h).

Distribution - Distribution patterns were identified on the basis of direct observations and indirect evidence such as burrows, scratchmarks and foot prints of *V. flavescens* during the transects survey. Local knowledge was used to identify the indirect signs of this species. Locations of observed individuals and indirect evidence were recorded with Global Positioning System (GPS) equipment and the data were used to create a spatial distribution map around Jagdishpur Reservoir by using ArcGIS 10.5 version (Panthi, 2011; Panthi *et al*., 2012; Aryal *et al.*, 2015).

Habitat Preferences - Habitat types used by *V. flavescens* such as swamp land and agricultural areas were maintained using transect surveys and intensive field surveys around Jagdishpur Reservoir. Different habitat parameters such as trees, shrubs and grasses, canopy cover, ground cover, agricultural land, land features, and swampy areas were recorded on each transect. Microsoft Excel was used to analyze the data and determine habitat preferences of this species.

Threats - Local residents of Jagdishpur Reservoir were interviewed to elicit information on the threats faced by *V. flavescens* around the reservoir. A total of 60 randomly selected respondents from different areas of Jagdishpur Reservoir within the study area were interviewed using a semi-structured questionnaire. Questions such as "Why is the population of *V. flavescens* decreasing?" and "For what purposes are people killing this animal?" were asked during the questionnaire survey. Issues were also assessed based on direct observations in the field. Habitat disturbances such as signs of grazing and feral animals, and the stumps of felled trees were used to visually assess habitat disturbance.

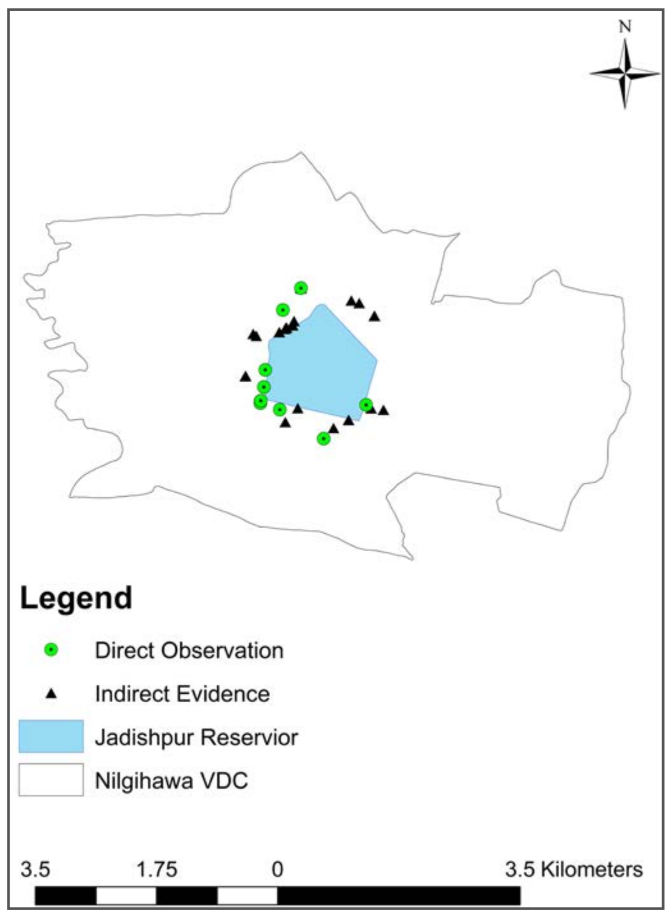

Fig. 1. Distribution of *Varanus flavescens* in the study area.

Results

Status of Varanus flavescens

Varanus flavescens was observed along 9 of 73 transects. As shown in Table 1, we observed 10 live individuals during transect surveys; six of which were adults and four were juveniles. Six of these observations were made in the swampy area around Jagdishpur Reservoir, whereas four individuals were sighted on agricultural land (Table 1).

Habitat Preferences

Habitat structure - Seventy percent of the potential habitat of *V. flavescens* at the study site was comprised of grasses, shrubs, trees and swampy areas, and 30% was comprised strictly of grasses.
Approximately 40% of *V. flavescens* were present in areas with dense ground cover (51-75% coverage) followed by 30% in areas with complete ground cover (76-100% coverage), 20% in areas with medium ground cover (26-50% coverage), and the remaining 10% were on open ground. Most of the potential habitats of this species were covered by the grasses *Impereta cylindrica* and *Saccaram spontanium*, and the shrubs *Ipomea carnea* and *Typha angustifolia*.

Land features - The majority of indirect signs of *V. flavescens* (indirect evidence such as burrows, signs of scratching, or foot prints) were recorded in the stream bed of Jagdishpur Reservoir. Ninety percent of indirect signs of this species were found in the streambed, whereas 10% were found in flat open terrain.

Threats to Varanus flavescens

During fieldwork, we identified anthropogenic activities such as recreational hunting and alleged safety concerns as major threats to *V. flavescens*. We also found that people hunt this species to protect fish farms, and for their skin (Fig. 2).

During the interviews, 52% of respondents stated that illegal hunting by local people around the reservoir area was the main cause for decreases in the *V. flavescens* population. Residents used various local materials such as sticks, stones, and agricultural tools for killing individuals of this species. They killed *V. flavescens* for recreation as well as for their skin and meat. Ten percent of respondents reported that the use of pesticides and insecticides was the main cause of its declination, whereas 15% of respondents said habitat destruction was the responsible factor for the decreasing population. Twenty three percent of respondents did not know the cause for declines.

Fifty five percent of respondents said that they killed this species for recreation; 17% of which claimed that *V. flavescens* was highly poisonous. Alleged poisonous substances excreted from the mouth of this species are believed to be physically dangerous to humans, so some people also appear to be killing this species for safety. Fifteen percent of respondents said that people killed the species because it predates fish; 8% said that people hunted this species for the skin to be used for making drums, and another 5% noted that *V. flavescens* was killed for its meat.

During the survey, it was reported that only men are involved in the killing of *V. flavescens*, and that women are not involved in such activities. It is mostly

Table 1. Observations of *Varanus flavescens* made at Jagdishpur Reservoir.

Time (h)	Populaton			Weather	Site
	Adult	Juvenile	Total		
0615	1	-	1	Sunny	Swampy area
0725	-	1	1	Sunny	Swampy area
0820	-	2	2	Sunny	Swampy area
1000	1	-	1	Sunny	Swampy area
1555	-	1	1	Sunny	Agricultural area
0915	1	-	1	Cloudy	Swampy area
1830	1	-	1	Sunny	Agricultural area
1725	1	-	1	Sunny	Agricultural area
0820	1	-	1	Sunny	Agricultural area
Total	6	4	10		

Fig. 2. *Varanus flavescens* killed by local residents.

local residents that are involved in killing activities, and represent the main conservation threat for *V. flavescens* in this area.

Discussion

The greatest number of *V. flavescens* encountered in this study were seen in swampy areas, which is consistent with other field studies on the species by Shah & Tiwari (2004) and Khatiwada & Ghimire (2009). Ghimire & Shah (2014) found that this species prefers wetland areas with few large trees. Our study found that this species occurred alongside streambeds and gently-sloped or flat terrain. It preferred dense ground cover (51-75%) over other habitat types and was more often found in areas with grasses and other ground cover than in strictly grassy areas.

Das (1988) reported that recreational killing of *V. flavescens* was a major threat to these lizards in eastern India. Anderson & Marcus (1992) identified improper land use, hunting, commercial use, inappropriate wetland management, harmful fishing practices, poisoning and overgrazing as major long-term threats to these lizards. Ghimire & Shah (2014) found that indiscriminate killing was a major threat to *V. flavescens* in Nepal. Similar to Khatiwada & Ghimire (2009) and Ghimire & Shah (2014), we have also found that poaching, particularly as recreation was the major conservation threat to this species in our study area. Children may be more responsible for killing this species in the country due to the lack of awareness about its importance (Ghimire *et al.,* 2014), and while some people in Nepal believe that eating the meat of monitor lizards can improve their health and act as a deterrent or possible cure for tuberculosis, leprosy, asthma, and piles (Shah & Tiwari, 2004), we found a lower number of respondents in our study area that claimed that this species is hunted for its meat.

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Living Among Water Monitors: An Exploratory Study of an Urban Water Monitor (*Varanus salvator*) Population in Bengkulu, Indonesia

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Abstract - *Varanus salvator* (Laurenti, 1768) is widespread throughout Southeast Asia and can be found living closely with humans in urban areas. In this study, the effects of trash piles on the size and capture frequency of *V. salvator* living on the campus of Bengkulu University (UNIB), Bengkulu, Indonesia were investigated. In addition, daily and weather pattern-related activity of *V. salvator* were evaluated. Four traps were set in strategic locations on UNIB's campus from 13 October to 28 November 2015; two were set close to trash piles (< 25 m), and two were set in more natural areas (> 200 m from trash piles). There were no significant differences in the size of *V. salvator* and their daily, seasonal activities, or proximity to trash piles. *Varanus salvator* were captured in greater frequencies at locations that were close to trash piles, more often in the morning than the afternoon and during drier weather. This study suggests that *V. salvator* activity could be affected by current and planned construction projects on UNIB's campus.

Introduction

The Asian water monitor (*Varanus salvator*) is the second largest lizard in the world, behind the Komodo dragon (*V. komodoensis*). *Varanus salvator* is very common throughout South East Asia, ranging from India and Sri Lanka to the Philippines and Indonesia, and is one of the most widespread varanid lizards (Bennett, 1995; Shine *et al*., 1998; Gaulke *et al*., 1999). The natural habitat of *V. salvator* includes forested habitat along rivers and other water bodies and mangroves (Bennett, 1995); however, water monitors are also found in cities in great densities. For example, large numbers of *V. salvator* are found in Lumpini Park and Dusit Zoo in Bangkok (Bundhitwongrut *et al*., 2008; Cota, 2011). The species has an indiscriminate diet, which includes a variety of food items ranging from invertebrates to vertebrates (Shine *et al*., 1998), and in urban habitats its diet may include human food waste and pets (Uyeda, 2009; Kulabtong & Mahaprom, 2015). Their ability to traverse large bodies of water (*e.g*., ocean barriers) via active swimming allows them to colonize remote islands quickly. For example, *V. salvator* became established on Krakatoa Island within 25 years of the 1884 Krakatoa volcanic eruption, a considerable time before any other terrestrial vertebrate colonization (Dammerman, 1945; Rawlison *et al*., 1990; Bennett, 1995).

Reproduction in *V. salvator* takes place throughout the year although it occurs with greater frequency at the start of the rainy season, with females producing multiple clutches of 6-17 eggs each year (Shine *et al*., 1998). Young *V. salvator* are more brightly colored than adults and spend most of their time in trees (Bennett, 1995)

Commercially, *V. salvator* is utilized for food (Nijman, 2015, 2016) and medicine (Uyeda *et al*. 2014) throughout South East Asia. Additionally, *V. salvator* is harvested for the leather industry (Shine *et al*., 1998), with their skins exported mostly to Europe and North America (Shine *et al*., 1996, 1998; Koch *et al*., 2013). Between 2000 and 2010 approximately 10 million *V. salvator* skins were exported predominately from Indonesia (63%) and Malaysia (33%; Koch *et al*., 2013). This commercial exploitation of *V. salvator* has led to localized population declines in Malaysia and Indonesia (Auliya, 2006). Other factors also contribute to population declines such as land use and habitat alteration (Koch *et al*., 2013); however, the relative significance of these variables has not been determined.

In Indonesia, *V. salvator* is not typically considered food by humans (Nijman, 2015); however, its meat is occasionally consumed as a novelty food, for medicinal purposes, and as an aphrodisiac (Nijman, 2016). Nijman (2015) estimated that in just 23 cities on Java, Indonesia, *V. salvator* are processed on the scale of tens of thousands of individuals per year. At this time, *V. salvator* is considered a species of least concern by the IUCN Red List because they are still very common throughout their range (Bennett, 1995; Bennet *et al*., 2010). However, Welton *et al*. (2013) suggested that there is a need for taxonomic identification of all lineages of the *V. salvator* complex due to the non-uniform distribution of harvesting pressures, which could change the IUCN status of this species.

This study investigated the impacts of campus life on the activity of *V. salvator* living on the grounds of Bengkulu University (UNIB), Bengkulu, Indonesia (Fig. 1) including seasonal distribution and the clustering of individuals around trash piles. On Tinjil Island, Indonesia, *V. salvator* were found in greater densities around trash piles than in natural forest habitats due to an abundance of human food waste (Uyeda, 2009). Since Uyeda (2009) found higher densities around trash piles, it was hypothesized that *V. salvator* will also occur in higher densities around trash piles on UNIB's campus.

Methods

Trapping was conducted biweekly over a seven week period from 13 October to 28 November 2015. Traps were constructed locally in Bengkulu out of steel with a top-down trap door (Fig. 2) and were baited with recently killed *Oreochromis niloticus* (or other common fish species found at the market) once per trapping period. A trap was sprung when a *V. salvator* attempted to bite the bait. Four traps were set out where there had been previous sightings of *V. salvator* by campus staff and students in an area measuring ca. 23 ha within UNIB's ca. 171 ha campus (Fig. 1). Traps one and three were located close to trash piles (ca. 23 and 25 m, respectively), whereas traps two and four were located in wet areas, farther away from trash piles (≥ ca. 225 m; Fig. 1). Traps one and three were under greater anthropogenic influence than traps two and four, although all trap locations were impacted by land use and UNIB's expansion with the construction of new buildings and roads. Traps were set at 0700 h and checked twice daily at 1300 and 1700 h, and monitored over two-day segments, twice a week (Tuesday–Wednesday and Friday–Saturday). This strategy allowed researchers to determine which part of the day individuals were trapped. Once a *V. salvator* was captured, data were collected, the animal was released,

Fig. 1. Trapping locations for *Varanus salvator* on the University of Bengkulu campus, Bengkulu, Indonesia.

and the trap was reset at the next trapping period. Snout-vent-length (SVL) and total length (TL) measurements were repeated three times for each individual to assure accuracy, with averages used in statistical analyses. Captured individuals were held down on a plywood board for SVL and TL measurements (Fig. 4). Sexing of *V. salvator* is typically done via probing (Bennett, 1995); to avoid potential injury, animals were not sexed in this study. Weather (dry vs. rainy), time of day (morning vs. afternoon), and location of capture were also recorded.

Each captured *V. salvator* received a three number identification mark applied on both dorsal lateral sides of the lizard with silver permanent markers (Fig. 3). The first number identified the trap in which the individual was initially captured (a number between one and four). The last two numbers were for individual identification (00–99). Marking the lizards allowed for the identification of recaptures and movements between trapping locations. Physical identifiers (*e.g.*, bite marks, scars, and plastics caught around skin) were also recorded due to the temporary nature of the marking system. To assist with individual identification, photographs of the ventral and dorsal sides of each lizard were recorded.

There were four weeks (eight trapping periods) of dry conditions (~5.08 mm rainfall; 13 October – 7 November 2015) and three weeks (six trapping periods) of rainy (~159.23 mm; 10 November – 28 November 28 2015) weather patterns over the course of this study (National Centers for Environmental Information, 2017). To account for the differences in collection times under dry and rainy weather conditions, the data were adjusted for trapping effort by finding the weekly averages of trapped *V. salvator*.

Descriptive statistics were utilized to show the

Fig. 2. Trap used to capture *V. salvator*. Wooden panels were added later to reduce a common nose injury seen in captured individuals.

Fig. 3. The marking technique used in this study.

Table 1. Number of *Varanus salvator* captures according to weather and time of day.

Parameter	Variables	Number of captures		*P* -value
		Traps 1 & 3	Traps 2 & 4	
Weather	Rainy	7	0	0.1456
	Dry	13	6	
Time of day	Morning	11	5	0.2663
	Afternoon	6	0	

differences between *V. salvator* size and other variables including trap location, time of day, and season. The data were tested for normality and homoscedasticity. An ANOVA and two sample t-tests were performed.

Results

In the seven weeks of trapping, a total of 26 captures were recorded, including 25 unique captures and one recapture (Table 1). The recaptured individual was captured in the same location as its initial capture. Snout-vent-length and TL of captured individuals were positively correlated (Spearman's Correlation Coefficient: S = 334, r_s = 0.591, p = 0.0142). Traps located near trash piles had more captures (n = 20) than locations further away from trash piles (n = 6; Fig. 4). There were no significant differences between body size and the location of capture (ANOVA: F = 0.0035, df = 1, p = 0.9538). Fifteen *V. salvator* were captured in the morning and six were captured in the afternoon. There was no significant difference between body size and time of capture (Two-sample t-test: t = 0.331, df = 15, p = 0.7451). Taking trapping duration into account, more individuals were captured weekly during drier weather ($\overline{x}$ = 4.75) than rainy weather ($\overline{x}$ = 2.33). There were no significant differences in the sizes of *V. salvator* captured in either season (Two-sample t-test: t = 1.1026, df = 15, p = 0.2876). Fisher's tests revealed no significant difference between the time of capture and weather pattern (*P*-value = 0.634), location of capture and time of day, or location of capture and weather pattern (Table 1).

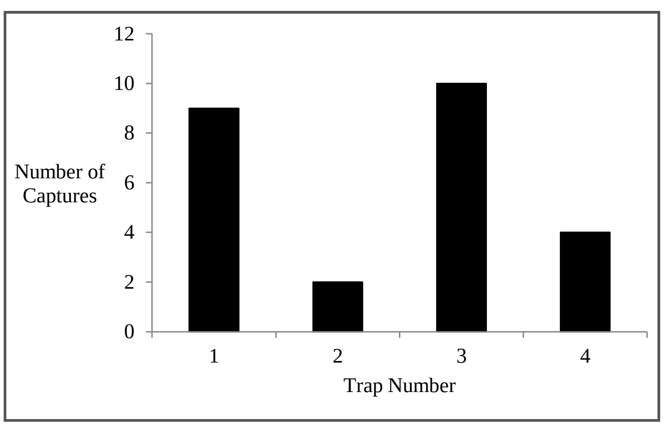

Fig. 4. The number of *V. salvator* captured at each location over a seven-week period (13 October to 28 November 2015). Traps one and three were located near trash piles (23-25 m), whereas traps two and four were located farther away (≥ 225 m).

Discussion

Only one *V. salvator* was recaptured and it was found in the same trap location as the original capture. This may suggest that movement between locations is limited; however, reluctance to enter a trap a second time may play a factor in this finding. Additionally, a caveat to this study is that the individual marking technique used was temporary, which could have skewed the data since these lizards shed their skin periodically. However, we also used visual identifiers to differentiate between individuals, and no individual with notable identifiers was captured twice.

The Bengkulu University campus is undergoing extensive development, and it is possible that *V. salvator* habitats will become increasingly fragmented. A new road has been constructed and a hospital is planned to be constructed where a pond currently exists; both of which are located near trap four (Fig. 1). In addition to campus expansion, another potential threat is general student life. *Varanus salvator* are commonly seen crossing roads on UNIB campus and most students avoid or pay no attention to them. In areas outside of the campus, *V. salvator* are considered to be pests when they eat pets or livestock; in such circumstances, people may kill monitors (UNIB students, pers. comm.).

There were no significant differences between the sizes of *V. salvator* captured in relation to any of the independent variables tested. This suggests that *V.*

salvator of all sizes may utilize the habitats in this area similarly. There were more *V. salvator* captured near trash piles than at locations farther away from the trash piles, which supports the findings of Uyeda (2009). The effects of trash piles and high concentrations of human food waste on *V. salvator* populations can be complex. For example, Uyeda *et al*. (2015) found that *V. salvator* had more agonistic interactions near trash piles. Further study is required to understand the effects of anthropogenic waste on urban *V. salvator* populations.

More *V. salvator* were captured in the morning than in the afternoon, suggesting that they are more active in searching for food during this part of the day. *Varanus salvator* is diurnal in nature and rarely active at night, although some nocturnal activity has been reported (Uyeda *et al.*, 2013).

On average, *V. salvator* were captured in greater numbers during drier weather. Shine *et al.* (1998) noted that this species experiences reduced reproduction during the dry season. Fewer individuals caught in traps during the rainy spell may be indicative of generally lower daily activity rates. Uyeda *et al*. (2015) found that there are seasonal shifts (dry vs. rainy) in trash pile interactions, attributed to natural prey items being more abundant in the rainy season. It has also been shown that *V. salvator* has larger home ranges during the rainy season when they fed on seasonally available food scraps from tourists on Tulai Island, Malaysia (Traeholt, 1997). However, food in trash piles on UNIB's campus is available year-round as there are only two two-week long academic breaks a year for UNIB students. Regardless, fewer captures during wetter weather may be attributed to prioritization of breeding over foraging.

Trash piles can have a considerable impact on the behavior and health of wild *V. salvator* populations. The trash piles at UNIB are situated around burn piles. Some trash is burned; however, the remaining unburnt trash accumulates and putrefies. These trash piles include items ranging from food scraps to plastic and industrial waste. Thus, it is conceivable that *V. salvator* are consuming toxic chemicals along with whatever food scraps they scavenge. For further investigation, there is anecdotal evidence from this study that *V. salvator* are consuming plastics in the areas of high trash density. Many *V. salvator* captured in this study would regurgitate plastic food bags when handled. Further exploration of the plastic consumption rate and the impacts on *V. salvator* living in anthropogenic environments would give a greater understanding of urban populations of *V. salvator*. Conservation efforts directed toward scavengers like the *V. salvator* must take into consideration the current food and waste disposal system in Indonesia and other developing countries around the world.

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New Records of the Blue-tailed Monitor, *Varanus doreanus* (Meyer, 1874), Including a Maximum Size Record

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Abstract - We refer to a previously unreported collection of *Varanus doreanus* from Irian Jaya, Papua New Guinea and Australia from 1933-1964. New locality information is provided and a new size record for the species (> 1.7 m) is presented.

Introduction

Varanus doreanus was described from northwestern New Guinea in 1874 but was considered a synonym of the widespread *V. indicus* for 120 years (Böhme *et al*., 2004). The species was revalidated by Böhme *et al*. (1994), who also designated a neotype for *V. doreanus* to replace the holotype, formerly deposited in the Staatliches Museum für Tierkunde, Dresden, which was destroyed during the Second World War. *Varanus doreanus* is a robust monitor lizard belonging to the *V. indicus* species group of the subgenus *Euprepiosaurus*, with a relatively large, bulky head and strong limbs. It is easily recognizable due to the greyish brown to blue-grey dorsal ground coloration, a dorsal pattern consisting of transversal rows of ocelli, a bluish tail, a light throat with dark marbling (which however, may be somewhat less conspicuous in individuals from southeast Papua and North Australia), a missing temporal streak, and a light tongue. Currently, *V. doreanus* is known from New Guinea and some offshore islands as well as from northernmost Queensland, Australia (Ziegler *et al*., 1999; Böhme *et al*., 2004; Ziegler *et al*., 2007; Weijola *et al*., 2016; Natusch & Lyons 2017). During a recent visit to the American Museum of Natural History (AMNH) by the senior author, specimens of *V. indicus* sensu lato were re-identified; among them were several *V. doreanus*.

Results

Based on their phenotypic appearance, especially the presence of a densely marbled throat and a light tongue, 18 individuals in the AMNH that were inventoried under the name *V. i. indicus* are reidentified as *V. doreanus* (see Table 1, Figs. 1-3). Indeed, the recently described *V. semotus* is difficult to distinguish from *V. doreanus* by external morphology (Weijola *et al*., 2017), but *V. semotus* is known only from Mussau Island in the northern Bismarck Sea, Papua New Guinea. Although *V. doreanus* is reported to occur all over New Guinea (Böhme *et al.*, 2004), there are only a few concrete localities published so far (Böhme *et al*., 1994; Ziegler *et al*., 1999; Weijola *et al*., 2016; Natusch & Lyons, 2017). The Idenburg River area in Irian Jaya, where the specimens AMNH 62620 and 62621 were collected, was not marked in the detailed map presented in Böhme *et al*. (1994). The same concerns the collection sites of Sturt Island in the Fly River in southwestern Papua New Guinea and Milne Bay in southeastern Papua New Guinea. Particularly interesting were records of *V. doreanus* from mainland Australia.

Ziegler *et al.* (1999) reported *V. doreanus* for the first time from Australia, based on the individual ZFMK 26341, deposited in the Zoologisches Forschungsmuseum Alexander Koenig (ZFMK) in Bonn, Germany, with the locality information “Northcoast, probably Cape York”. ZFMK 26341 was sent in the year 1876 to the Zoological Museum of the Georg-August-University in Göttingen, Germany by R. Schütte, brother-in-law of Wilhelm Keferstein, curator in the Museum in Göttingen (see Böhme & Bischoff, 1984), who had regularly sent amphibians and reptiles from Australia to Göttingen (Keferstein, 1867, 1868). The specimen was inventoried in the herpetological collection of the ZFMK in the year 1977, when the entire herpetological collection from the museum in Göttingen was transferred to the museum in Bonn. According to Natusch & Lyons (2017), herpetologists did not recognize the species’ occurrence in Australia until recently (Cogger, 2014; Wilson, 2015). When studying specimens labelled as *V. indicus* in the Queensland Museum, Australia, Weijola *et al.* (2016) reported on three specimens of *V. doreanus* from Cape York, Claudie River, and Pascoe River in Queensland (Natusch & Lyons, 2017). The latter authors also were able to record several *V. doreanus* during field research at the northern tip of Cape York Peninsula, in the vicinity of the Lockerbie Scrub, Australia. Herein, we once more confirm the occurrence of *V. doreanus* in mainland Australia and provide additional localities based on the four specimens AMNH 69395 and AMNH 69509-69511, which were collected May–August 1948

Table 1. Localities for *Varanus doreanus* in the collection of the American Museum of Natural History (AMNH); a.s.l. = above sea level.

Region	Voucher	Collection data
Irian Jaya, Indonesia	AMNH 61885	“Hollandia”, W. B. Richardson, 3rd Archbold (Indisch-Amerikaansche) Expedition, 18 July 1938
	AMNH 61886	“Hollandia”, W. B. Richardson, 3rd Archbold (Indisch-Amerikaansche) Expedition, 18 July 1938
	AMNH 61889	“Hollandia”, W. B. Richardson, 3rd Archbold (Indisch-Amerikaansche) Expedition, 3 July 1938
	AMNH 61890	“Hollandia”, W. B. Richardson, 3rd Archbold (Indisch-Amerikaansche) Expedition, June - July 1938
	AMNH 61896	“Hollandia”, W. B. Richardson, 3rd Archbold (Indisch-Amerikaansche) Expedition, 16 July 1938
	AMNH 62620	“Bernhard Camp, Idenburg River”, 75-80 m a.s.l., W. B. Richardson, 3rd Archbold (Indisch-Amerikaansche) Expedition, April 1939
	AMNH 62621	“Bernhard Camp, Idenburg River”, 75-80 m a.s.l., W. B. Richardson, 3rd Archbold (Indisch-Amerikaansche) Expedition, April 1939
Papua New Guinea	AMNH 57548	Archbold Expeditions to New Guinea, 1933-1964
	AMNH 59933	“Sturt Island”, 2nd Archbold Expedition, October 1936
	AMNH 59934	“Sturt Island”, 2nd Archbold Expedition, October 1936
	AMNH 59957	“East Bank, Fly River”, Archbold & Rand
	AMNH 59958	“Sturt Island”, Archbold & Rand, 2nd Archbold Expedition, October 1936
	AMNH 59959	“Sturt Island”, Archbold & Rand, 2nd Archbold Expedition, October 1936
	AMNH 74417	Milne Bay: “Peria Creek Crossing, Kwagira River”, 50 m a.s.l., H. van Deusen, 4th Archbold Expedition, 25 August 1953
Queensland, Australia	AMNH 69395	“Newcastle Bay, 2.5 min. S of Somerset”, Archbold Cape York (Australia) Expedition, 11 May 1948,
	AMNH 69509	“Rain forest, Rocky Scrub, Nesbit River, Lakelands, Leo Creek”, 1500 ft. a.s.l., Archbold Cape York (Australia) Expedition, 17 August 1948
	AMNH 69510	“Rain forest, Rocky Scrub, Nesbit River”, 1500 ft. a.s.l., Archbold Cape York (Australia) Expedition, 17 August 1948
	AMNH 69511	“Rain forest, Rocky Scrub, Nesbit River”, 1500 ft. a.s.l., Archbold Cape York (Australia) Expedition, 17 August 1948

Fig. 1. Hatchlings of *Varanus doreanus* from Irian Jaya, Indonesia (AMNH 61885, 61886, 61890). Photographed by **Thomas Ziegler**.

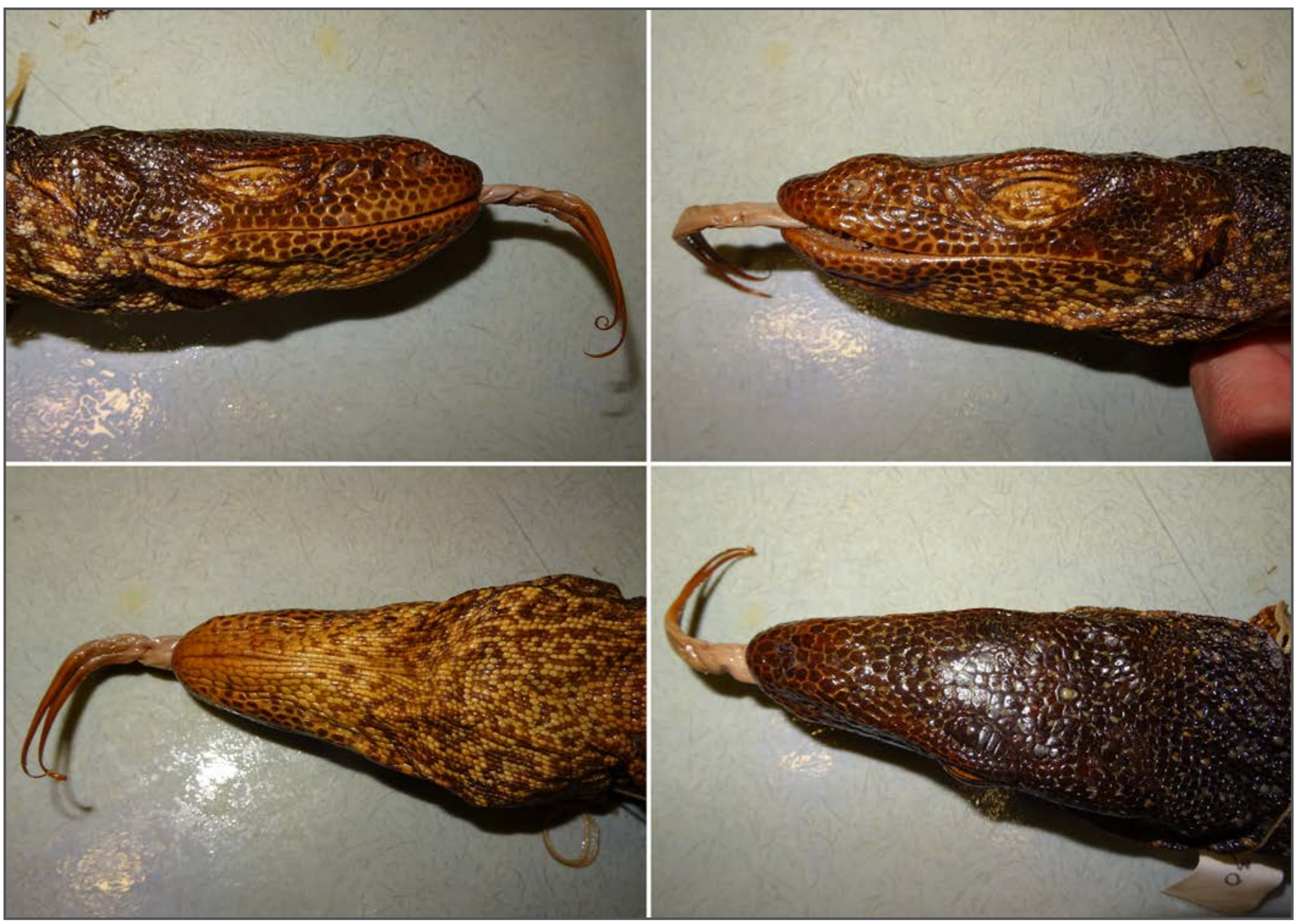

Fig. 2. Head views of an adult *Varanus doreanus* from Milne Bay, Papua New Guinea (AMNH 74417). Photographed by **Thomas Ziegler**.

Fig. 3. Head views of an adult *Varanus doreanus* from Nesbit River in Queensland, Australia (AMNH 69511). Photographed by **Thomas Ziegler**.

(see Table 1). All Australian *V. doreanus* deposited in the AMNH were collected from the Cape York Peninsula, with Somerset being located at the northernmost tip of the peninsula, and the Nesbit River on the eastern coast of central Cape York Peninsula. These new records are concordant with the distribution in Natusch & Lyons (2017) for *V. doreanus*, *viz*., both at the extreme northern tip of the Cape York Peninsula and in the Iron, Kawadji-Ngaachi, and McIlwraith ranges on the eastern coast of central Cape York Peninsula.

AMNH 69395 also represents a new size record for the species. Böhme *et al*. (2004) indicated about 135 cm total length as a maximum size for *V. doreanus*. Natusch & Lyons (2017) reported a sexually mature (potential) male with a 63 cm snout-vent length and 91 cm tail length. With a total length of 154 cm, that male represented the maximal size record for this species. In addition, Natusch & Lyons (2017) assumed maximum size in *V. doreanus* to be < 1.6 m. The snout-vent length of AMNH 69395 examined by us in April 2018 measured 83.5 cm, measured from the snout tip to the cloacal slit, and the tail measured 90 cm from the cloaca to the tip of the tail, resulting in a total length of 173.5 cm, thus representing a new size record for the species. However, the individual must have been even larger, as the tail tip was missing. The specimen's large size, massive head (Fig. 4), and inverted, fixed copulatory organs, indicate that it is a male. Other character states are consistent with previously reported variation including tongue coloration, marbled throat, which are diagnostic for *V. doreanus*, and midbody scale count (166), which falls within the range (154-180) in Böhme *et al*. (2004).

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Fig. 4. Largest known *Varanus doreanus* from the northernmost tip of the Cape York Peninsula in Queensland, Australia (AMNH 69395). Photographed by **Thomas Ziegler**.

author's trip to the USA in April 2018 possible. Thanks to David Kizirian (AMNH, New York) for his permission to study the monitor lizards under his care and for providing locality information and useful comments on an earlier version of the manuscript. Anna Rauhaus (Cologne Zoo) kindly prepared the figures.

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An Annotated Bibliography of Captive Reproduction in Monitor Lizards (Varanidae: *Varanus*). Part III. *Soterosaurus*

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Abstract: Popular in zoos and private collections, monitor lizards have been maintained in captivity for nearly two centuries. During this time, but especially over the past three decades, a voluminous body of publications has brought to light important details and perspectives that have helped advance their captive husbandry and reproductive management. This bibliography presents an annotated compilation of publications pertaining strictly to the captive reproduction of monitor lizards belonging to the *Varanus* subgenus *Soterosaurus*, commonly known as water monitors. It is intended to serve as a guide for zoos and private herpetoculturists looking to expand their knowledge and familiarity with this group and introduce readers to different perspectives on their management and reproduction in captivity.

Introduction

Monitor lizards have a long and fascinating history of being maintained in captivity that dates back to at least the early 19th Century. Some of the earliest published accounts of monitor lizards in captive collections reference animals held in European menageries and zoological gardens (Cox, 1831; Knight, 1867; Mitchell, 1852; Sclater, 1877), although private keepers also maintained representatives of this group during this period (Bateman, 1897; Lachman, 1899; von Fischer, 1884). Alfred "Gogga" Brown was probably the first individual to genuinely attempt to reproduce monitor lizards in captivity in the late 1800s (Branch, 1991). Although he received hundreds of eggs (from 33 clutches) from a large group of more than 40 captive *Varanus albigularis* he maintained outdoors in South Africa, he was unsuccessful in hatching any live offspring (Branch, 1991). Eggs had also been received but not hatched by other keepers around this time (*e.g.*, Thilenius, 1898); these eggs were usually scattered by the females who clearly did not have appropriate conditions available for nesting (Branch, 1992; Thilenius, 1898). A poor understanding of monitor lizard biology and husbandry and reptile egg incubation undoubtedly prohibited successful captive breeding from taking place for many decades. This was especially apparent in a 1967 report by Osman (1967), who, while discussing a clutch of *V. komodoensis* eggs that were scattered across the ground of the enclosure rather than buried, suspected that the eggs were to be later buried in the sand by the female after they had been left out in the sun for the shells to harden.

The first documented record of successful captive breeding of a monitor lizard occurred with *V. komodoensis* in 1941 (de Jong, 1944). Unknown to their caretakers, a pair of adults maintained at the Batavia Zoo since 1938 secretly nested a clutch of eggs in their exhibit which unexpectedly hatched several months later, much to the zoo's surprise. The next documented case of successful captive reproduction in monitor lizards did not occur until 1962, when a wild-caught gravid *V. albigularis* produced a clutch of eggs shortly after arriving at the San Diego Zoo, which resulted in a single hatchling (Staedeli, 1962). Several additional species were successfully bred for the first time in the 1970s (Horn, 1978; Horn & Visser, 1989), with more species hatched in the 1980s (*e.g*., Bredl & Horn, 1987; Bröer & Horn, 1985; Eidenmüller, 1986; Eidenmüller & Horn, 1985; Horn & Petters, 1982; Horn & Visser, 1989; Irwin, 1996; Stirnberg & Horn, 1981). From the 1990s onward, monitor lizard husbandry continued to advance rapidly, to the point where at least 53 species have now been successfully reproduced in captivity (Horn & Visser, 1997; Eidenmüller, 2007; Husband & Bonnett, 2009; Brown, 2012).

In previous bibliographic installments, I have focused on the *Varanus* subgenera *Odatria, Empagusia* and *Phillipinosaurus* and the *V. prasinus* complex belonging to the subgenus *Euprepiosaurus* (Mendyk, 2015, 2016, 2017). Here, the focus is directed towards species belonging to the subgenus *Soterosaurus*, and more specifically the *V. salvator* species complex; otherwise known as water monitors. This group is currently comprised of nine semi-aquatic species that are distributed throughout southern and Southeast Asia, and numerous islands throughout the Indo-Australian Archipelago. Although a Sri Lankan *V. salvator* currently holds the record for the longest lizard ever recorded, at 3.21 m in total length (Randow, 1932), *V. komodoensis* regularly reaches larger sizes and proportions. Still, members of the *V. salvator* complex rank among the largest lizards in the world, and are certainly the most commonly kept of the giant monitor species. Several species belonging to this group including *V. salvator*, *V. cumingi*, *V. nuchalis*, *V. togianus* and *V. marmoratus* have been maintained in captive collections; however, documented cases of successful captive reproduction are known only for two species: *V. salvator* and *V. cumingi*. The following bibliography, which represents a continuation of what will be several installments on the captive breeding of monitor lizards, focuses chiefly on water monitors belonging to the subgenus *Soterosaurus*. Similar works that address other subgenera are forthcoming.

Using this Bibliography

This bibliography covers all aspects of captive reproduction including both successful and unsuccessful attempts. It is largely intended to serve as a resource for zoo professionals and private herpetoculturists working with these species in captivity, but may also prove valuable to conservation biologists, ecologists, veterinarians and general enthusiasts seeking to gain familiarity with existing literature on the reproductive biology of monitor lizards. Species covered in this bibliography are organized alphabetically, with annotations describing the nature and content of each work appearing inside brackets after each reference.

Increased interest in the taxonomy and systematics of the *V. salvator* complex over the past decade has led to various taxonomic revisions of the complex (Koch *et al*., 2007; Welton *et al*., 2013) as well as the description of several new species and subspecies (Koch & Böhme, 2010; Koch et al., 2010; Welton *et al*., 2014). Therefore, although best efforts were made to properly assign each publication to the appropriate taxon, due to limited information, it is possible that some accounts listed for one species may represent that of another.

While best efforts were made to document all known publications relevant to the reproduction of these species in captivity, I recognize the possibility and likelihood that some publications may have been missed. Given that bibliographies are perpetual works in progress, I welcome and encourage feedback on publications missing from this bibliography and new accounts as they are published so that they can be added to an updated version of this document in the future.

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Subgenus: Soterosaurus

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Varanus cumingi. Captive. Photographed by **John Adragna**.

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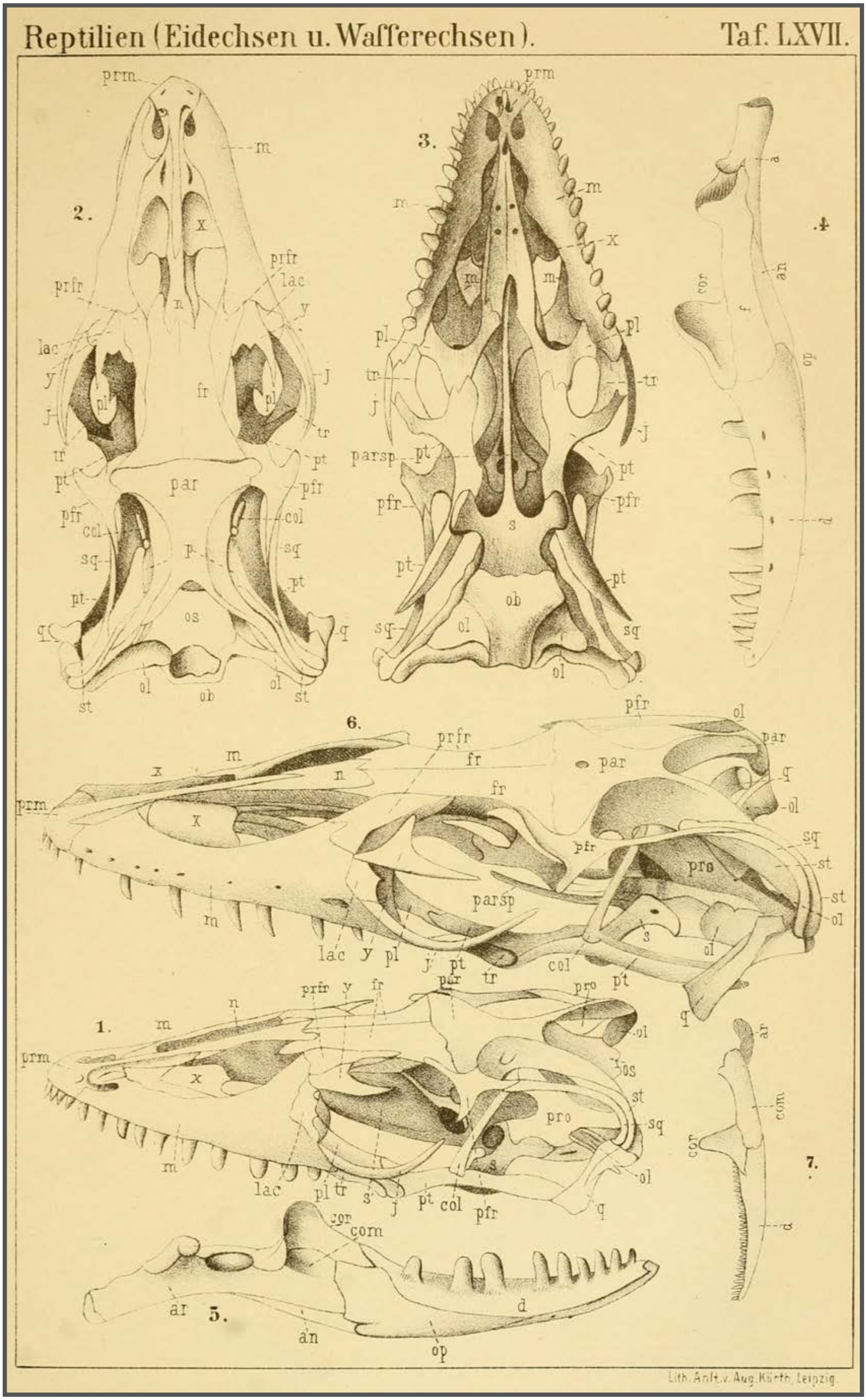

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