
BIAWAK
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On the Cover: *Varanus rudicollis*

The adult *Varanus rudicollis* depicted on the cover and inset of this issue was photographed by **Gail Baird** and **Dan Bernard** (131 Design Ltd UK) on 20 December 2011 in primary forest at Permai Rainforest Resort, located ca. 25 km north of Kuching, Sarawak, Malaysian Borneo. The monitor was initially seen foraging around the roots of a tree in the late afternoon, around 1500 h. Once spotted, it ascended the tree to a height of about 1.5 m where it then froze, allowing for photographs to be taken from a distance of 2 m for approximately 20 minutes.

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Journal of Varanid Biology and Husbandry

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 monitor 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 panoptes panoptes. Iron Range NP, Queensland. Photograph by **Steve Kacir** (http://www.flickr.com/photos/sekacir/)

BIAWAK Celebrates its Sixth Year of Publication

Since its inception in 2007, the International Varanid Interest Group has grown steadily in terms of membership and the number of countries reached. As of May 2012, IVIG membership totaled an impressive 691 individuals from 49 nations (Figs. 1 & 2). In retrospect, the success and global distribution of *Biawak* can be attributed to its open-source electronic format, and would not have been possible if it were offered as a print publication due to various logistical problems and associated expenses. As a volunteer-based publication, *Biawak* has been successful in increasing its membership and presence within the herpetological community without any paid marketing or advertising campaigns, relying primarily on word of mouth promotion by its members. We hope that our members continue to support and share this free informational resource with others interested in varanid lizards, or herpetology in general.

As *Biawak* now enters its sixth year of publication, some changes have been enacted which should help ensure the success and longevity of this specialized publication. Most notably, until further notice, the publication frequency of *Biawak* will be reduced from four issues a year to two. It is believed that this is the best strategy to prevent publication delays in the future. Some changes have also been made to the editorial board, and the IVIG is currently seeking editorial and zoo liaisons from North America, Europe, Africa, Asia, and Australia to help promote *Biawak* and encourage greater participation from zoos in the exchange of information and collaboration with the international varanid community.

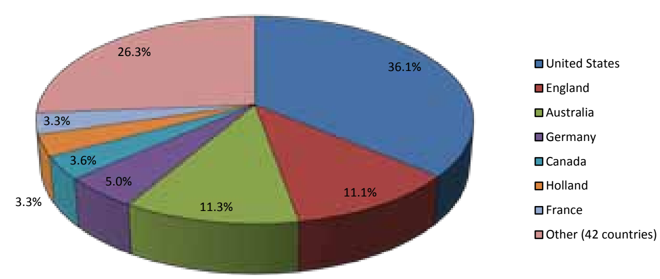

Fig. 1. Breakdown of IVIG membership by country.

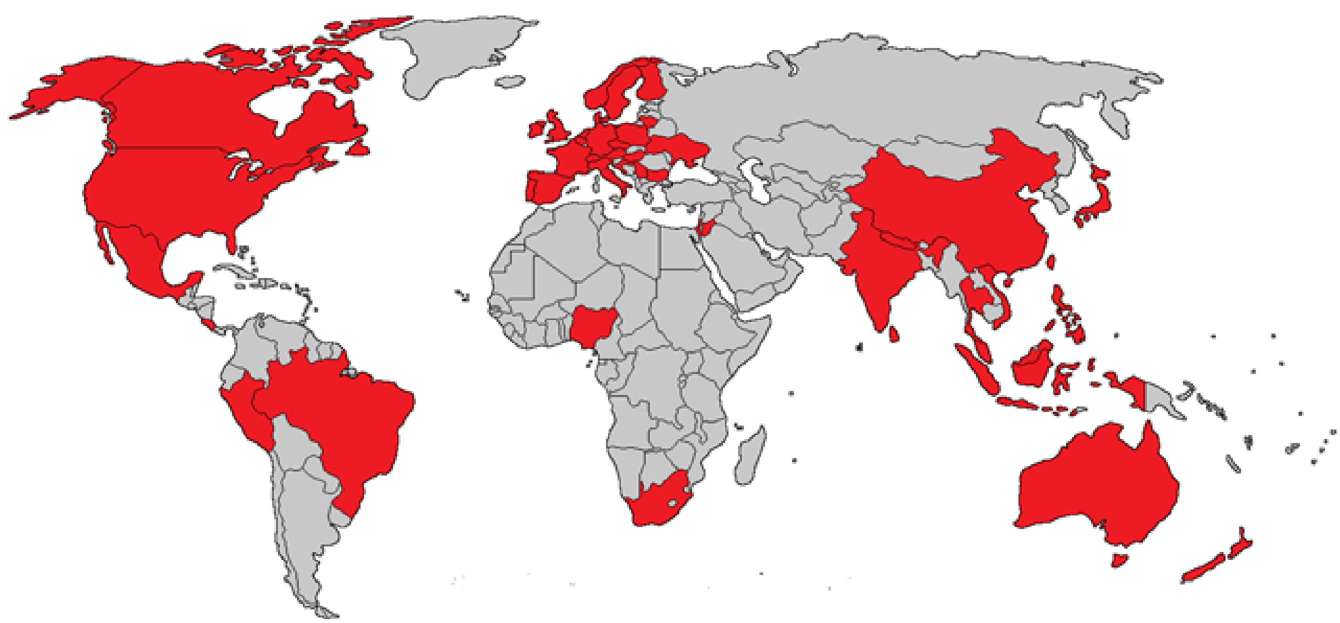

Fig. 2. Current global distribution of IVIG membership as of May 2012.

The continued success of *Biawak* depends entirely on participation from the international varanid community, including a steady supply of written and photographic submissions from academics, zoo professionals, veterinarians, private herpetoculturists, and enthusiasts. As long as we continue to receive manuscripts and photographic submissions, we will continue to produce this much-needed informational resource.

-RWM

A Call for Papers

The IVIG is currently seeking written submissions pertaining to the biology, natural history, and captive husbandry and reproduction of varanid lizards for publication in its international research journal *Biawak*. Full-length research articles and brief reports on varanid natural history, keeping and breeding, and behavior are welcomed, as well as English translations of previously published works, abstracts of current varanid research, historical facsimiles and biographies, bibliographies, and book reviews.

Assistance with manuscript preparation for first-time or novice authors is available when requested and translational assistance may be available to authors whose primary language is not English. For style, format, and photographic specifications, guidelines are available on the IVIG website: http://varanidae.org. All submissions, including manuscripts and photographs, and any further questions should be directed to Robert Mendyk, editor, at odatriad@yahoo.com.

Varanus caudolineatus. Loma Glen, WA. Photograph by **Judy Dunlop.**

Two Komodo Dragon Deaths at Surabaya Zoo

Two Komodo dragons (*Varanus komodoensis*) have died at Surabaya Zoo, East Java, Indonesia. An eight year-old female was first found dead on 23 October 2011, and on 8 November a second dragon – a 20 year-old of undisclosed gender – was also found dead. Though the first animal did not show signs of illness prior to its death, the second specimen was said to have been sick and showing little movement. The causes of death have yet to be released though infection is suspected for at least one individual. Necropsies are currently underway.

Sources: Jakarta Globe; 25 October 2011, 8 November 2011

Komodo Dragon Hatches at Memphis Zoo

On 8 October 2011, a single Komodo dragon (*Varanus komodoensis*) hatched at the Memphis Zoo (USA) after 222 days of incubation. All other eggs in the eight egg clutch laid in February 2011 were infertile, and the hatching weighed 99 g upon its emergence from its egg. Until DNA testing is performed, it is unknown whether the hatchling was fathered by either of the zoo's two male dragons, or if this event represents a further case of parthenogenesis in the species. The zoo plans to keep the individual until it reaches around a meter in length.

Source: reptilechannel.com; 28 November 2011

Wild Reptiles Seized in Vietnam

Police officials in Ha Tinh province, Vietnam recently seized a total of 1,953 kg of wild animals that were being transported illegally inside a vehicle. Among the seized animals were 151 kg of snakes, 963 kg of turtles, and 839 kg of Asian water monitors (*Varanus salvator*). When interrogated, the driver informed police that he was transporting the animals to a magnate, but could not show proper documentation of the animals' legal origins. The confiscated animals were delivered to the province's forest protection department, and were subsequently sold at an auction the following day since none represented endangered species.

Source: Vietnamnet.vn; 27 December 2011

Film Criticized for Alleged Illegal Use and Torture of Monitor Lizard

A social activist filed a court complaint against the Indian movie Udumban for allegedly illegally capturing a monitor lizard (species not specified) for use in the film and torturing the specimen. A hearing was scheduled for 16 February, just days after the movie's intended release. The producer of the film denies any wrong doing and states that permission was granted by forestry officials before using the lizard in the film.

Source: behindwoods.com; 2 February 2012

Varanus niloticus. Kruger NP, South Africa. Photograph by **Frik Reasmus**.

Monitor Lizard Rescued from Illegal Wildlife Traders

A 1.2 meter long monitor lizard (probably *Varanus bengalensis*) was seized from illegal wildlife traders at the Indian National Army Market in Delhi, India on 7 December 2011 after officials received a tip-off about the animal being offered for sale. It was suspected that the animal originated from Rajasthan. The species is protected under the Wildlife Protection Act of 1972, and violations of the act can result in imprisonment and hefty fines. The confiscated animal was delivered to a wildlife center for care and observation.

Source: The Indian Express; 8 December 2011

Komodo Dragons to Australia?

Recent comments made by Professor David Bowman of the School for Plant Science at the University of Tasmania in an essay pertaining to the control of invasive plant and animal species in Australia have generated considerable media attention and mixed reactions. In addition to proposing the release of large herbivores such as elephants and rhinoceros as a way of controlling introduced plant pests in Australia, Bowman also suggested that, "We could introduce predators such as the Komodo dragon, which would fill the niche of the giant lizards that once thrived in Australia", as a way of controlling invasive animal pests such as pigs and goats.

Source: Adelaidenow.com.au; 2 February 2012

Emerald Tree Monitors Seized in Sydney

During a series of raids on three houses in suburban areas of Sydney, Australia, officials discovered and seized a total of 194 live reptiles. Several of the species seized had never before been seen in Australia, and the value of the seized animals has been estimated at more than $500,000 AUD. Among the exotic species discovered were crested geckos, leopard geckos, boa constrictors, and two emerald tree monitors (*Varanus prasinus*). Charges are expected to be made once a full investigation is completed. Many of the seized animals were purported to be in poor physical condition and have since been transferred to various wildlife centers.

Source: The Daily Telegraph; 20 February 2012

Varanus salvator macromaculatus consuming a freshwater eel. Chinese Garden, Singapore. Photograph by **Christopher Chia.**

Bulgarian Officials Seize Komodo Dragons

Bulgarian customs officials have confiscated six Komodo dragons (*Varanus komodoensis*) which were being smuggled into the country. The animals were part of a large shipment including a variety of other reptiles that an unnamed Bulgarian national had packed in suitcases and was attempting to bring in from the Czech Republic. The animals are currently being held at the Sofia Zoo. An official noted that illegal wildlife trafficking has been increasing in the country since its entry into the European Union in 2007 and the resulting relaxation in border control.

Source: Reuters; 12 March 2012

Komodo Dragon Dies at Pittsburg Zoo

According to zoo officials, a Komodo dragon (*Varanus komodoensis*) kept at the Pittsburgh Zoo & PPG Aquarium (USA) died during surgery. The eighteen year-old male, named Noname, had undergone surgery to correct a possible intestinal blockage revealed by x-rays. This had followed a bout of constipation and complete refusal of food. Noname originally came to Pittsburgh in 1997 after being hatched four years earlier at the National Zoo; part of the second clutch of dragons to ever be produced in the United States. Zoo officials commented that Noname was particularly docile and visitors would occasionally be permitted to enter his enclosure. A necropsy has been performed, though details have not yet been made available. Officials noted that the use of anesthesia may have played a part in his death.

Source: Pittsburg Tribune-Review; 12 March 2012

Komodo Dragon Dies at Miami Metrozoo

An approximately 24 year old male Komodo dragon (*Varanus komodoensis*) residing at Miami Metrozoo (USA) passed away on 13 April 2012. Although the dragon had been lethargic days leading up to its death, there is no clear cause of death. An official cause will be determined once a necropsy has been performed. The male arrived at the zoo in 1995 from Taman Safari Park, Indonesia, and sired 27 hatchlings in 1998.

Source: http://miami.cbslocal.com; 13 April 2012

Komodo Dragons to be Displayed at Riverbanks Zoo

For the first time in its history, Riverbanks Zoo (South Carolina, USA) will be displaying Komodo dragons (*Varanus komodoensis*) in the Desert Gallery of its Aquarium Reptile complex. The two juveniles to be displayed were hatched by Los Angeles Zoo in 2011, and have been housed behind the scenes at the zoo as a new indoor exhibit was converted for them.

Source: http://thestate.com; 2 May 2002

Varanus albigularis. East Tsavao NP, Kenya. Photograph by **Lisa Kimathi.**

Report from the Fourth Annual Meeting of the "AG Warane und Krustenechsen"

The fourth annual meeting of the AG Warane of the German DGHT took place on 19-20 May 2012 in Esslingen near Stuttgart. As with the year before, the annual meeting lasted two days. While the first day was reserved for talks and the general meeting of the group's members, the second day was dedicated to visiting Wilhema, the zoological and botanical garden of Stuttgart, which was the closing highlight of this year's annual meeting.

On Saturday morning, the program began with a talk by Uwe Krebs (Ansbach) about his experiences in Australia west of the 'toad line'. Therein, he reported on the monitor lizards he found in the Kimberley region in northwestern Australia, where the invasive cane toad (*Bufo marinus*) has not yet been recorded. Monitor species introduced to the audience included *Varanus panoptes, V. tristis* and *V. mertensi*. Next, André Koch (Museum Koenig, Bonn) talked about the "Distribution, threats and conservation status of the monitor lizards of Southeast Asia and the Indo-Australian Archipelago". He made clear the importance of this vast island region as the major center of diversity and endemism of monitor lizards. Currently, 43 different monitor species are recognized from Sri Lanka in the west through continental Southeast Asia and the Indo-Australian Archipelago to the various islands of the Pacific. At the same time, many species of this region, such as the widespread *V. salvator* and the endemic *V. macraei* and *V. yuwonoi*, are focal species of the international trade of monitors as pets and skins. After that, Yannick Bucklitsch (Museum Koenig, Bonn) gave a short lecture "About the use of the scale microstructure of monitor lizards for systematic investigations". For details see page 57 of this issue.

Before the lunch break, the general meeting of AG-Warane members took place. Thomas Hörenberg (Stuttgart) informed members that Kay Dittmar has retired from the position of leader of the AG Warane for personal reasons, and thanked him, in his absence, for his engagement in the AG since it was re-established in 2008. Next, Thomas Hörenberg introduced the idea to include heloderms (*Heloderma* spp.) into the AG Warane and to rename it into "AG Warane und Krustenechsen" as it was formerly known in the 1990s. This proposal found broad acceptance. A new board of the working group was also elected. Thomas Hörenberg was confirmed as the new leader and André Koch continues his position as scientific leader. The advisory board is completed by Ramona Jünemann (Northeim) and Manfred Gessner (Wesseling), who were also confirmed.

After the lunch break, Frank Jünemann (Northeim) talked about his "Experiences in keeping the little-known peach-throated monitor lizard (*Varanus jobiensis*)". Interestingly, Frank keeps two different color morphs of this New Guinean monitor species. Subsequently, Jochen Geiger (Wernau) presented some slides from a trip to western Malaysia and Borneo, where *V. salvator macromaculatus* and *V. bengalensis*, as well as many other reptiles and amphibians were observed. The learning ability and adaptability of a Mindanao water monitor (*Varanus cumingi*) was the topic of an interesting talk by Frank Körner (Diekholzen). Therein, Frank reported about the relationship with his tame monitor lizard Don. Finally, Thomas Hörenberg reported on the husbandry and breeding of *Heloderma h. horridum* and *H. horridum exasperatum*.

Afterwards, the warm summer evening in Esslingen was spent together talking about monitor lizards, the football match between Bayern München and FC Chelsea, and various other topics. Even two guests from Great Britain joined the attendees of the meeting to get in touch with the German varanid community.

The second day of the meeting was entirely reserved for visiting the zoo in Stuttgart. During a guided tour through the terrarium, *V. gilleni*, *V. timorensis*, *H.*

horridum, *H. suspectum* and many other amphibians and reptiles were observed. The beautiful flowers and greenhouses of Wilhelma also made this visit a pleasant event before the attendees returned home.

The advisory board of the AG Warane und Krustenechsen thanks all referees for their informative talks.

- Thomas Hörenberg & André Koch

Attendees of the fourth annual meeting of the AG Warane und Krustenechsen.

Wilhelma, zoological and botanical garden in Stutgart.

ARTICLES

Biawak, 6(1), pp. 11-21

Observations on Parthenogenesis in Monitor Lizards

RALF WIECHMANN
Langenstücken 137
21335 Lüneburg, Germany
E-mail: R_A_Wiechmann@gmx.de

Abstract - In this article I report observations on multiple parthenogenetic events in the Argus monitor (*Varanus panoptes*) in captivity. Two individually-housed females produced a total of 14 clutches of eggs in the absence of a male over a period of seven years. To date, 23 out of 69 eggs received from eight clutches have been incubated; all others eggs were noticeably infertile and discarded. Embryos developed in at least ten eggs; nine of which died shortly before hatching. Only one offspring successfully hatched and survived. Two non-surviving embryos showed cranial deformities. Also discussed are the different forms of parthenogenesis known to birds and reptiles, specifically highlighting the details of facultative parthenogenesis in the genus of *Varanus.*

Introduction

Parthenogenesis is not commonly reported in reptiles. Vrijenhoek *et al*. (1989) recorded parthenogenetic reproduction in the following lizard families: Gekkonidae, Teiidae, Uromastycidae (Agamidae), Chamaeleonitidae, and Xanthusiidae. Böhme (1975) and Frey & Madden (1995) reported parthenogenesis in two additional lizard families: Corytophanidae and Iguanidae. Parthenogenesis has also been documented in several snake groups (Magnusson, 1979; Vrijenhoek *et al*., 1989; Dubach *et al*., 1997; Schuett *et al*., 1997; Scalka & Vozenilek, 1986; Groot *et al*., 2003; Kuhn & Schmidt, 2004).

In recent years, several reports of parthenogenesis in captive monitor lizards have been published. Lenk *et al*. (2005) documented a successful parthenogenetic breeding of *Varanus panoptes horni*, Watts *et al*. (2006) described a case for *V. komodoensis*, and Hennessy (2010) reported a case for *V. ornatus*. Incidents of parthenogenesis in captive monitor lizards could potentially be noticed more frequently if individuals were housed separately and not in pairs, although this is only speculation. Typically, if a clutch of eggs is produced while a sexual pair is housed together, it is automatically assumed to be the result of normal sexual reproduction. The following is a report of my observations on the husbandry and parthenogenetic reproduction of *V. panoptes* in captivity.

The animals

A single *V. panoptes* was purchased from a pet shop as a sub-adult on 15 September 2003 (Figs. 1 & 2). This animal was captive-bred in Germany, and had hatched in January 2003. It was offered for sale together with seven other siblings from the same clutch. This lizard and its siblings were assumed to be hybrids of *V. p. panoptes* and *V. p. horni* because of their coloration and pattern. Some of the siblings showed coloration and markings typical of *V. p. panoptes*, whereas others resembled *V. p. horni.* This assumption was later confirmed in an interview with the breeder. On 12 October 2003, the snout to vent length (SVL) of this animal measured 20 cm; total length (TL) was 52 cm.

Keepers of *V. panoptes* have reported that males of this species tend to grow much larger, but are easier to handle than females. Keeping this in mind, I sought to


Figs. 1 & 2. The first female (*Varanus panoptes panoptes* x *V. panoptes horni*), photographed in June 2006.

purchase a single animal, preferably a male. At the pet store, the largest individual from the group was chosen; it displayed the coloration and pattern of *V. p. panoptes.* Unfortunately, this animal turned out to be female, and in December 2004 produced its first clutch of eggs. Since this animal was a sub-adult when purchased in September 2003 and did not have contact with another monitor lizard since it was acquired, it was presumed that the clutch might have been produced through parthenogenesis.

Upon the discovery that this initial specimen was female, I set out to purchase a suitable male of the same subspecies. This, however, was not possible, as only *V. p. horni* offspring were available. Therefore, the largest animal from a clutch of *V. p. horni* hatchlings which had hatched just a few days earlier was purchased directly from a private breeder on 9 September 2006 (Figs. 3, 4 & 5). Unfortunately, this animal also proved to be female when it laid a clutch of eggs in 2009.

Husbandry

Past experiences from other private keepers suggested that housing two or more individuals of this species together in the same enclosure could lead to problems of aggression. Even housing two females together can be hazardous and often does not work out. Knowing there was a possibility of aggression, it was decided that both animals should be housed separately. The enclosure for the first individual offered 2.8 m^2 of floor space; the enclosure for the second individual offered 5 m^2 of floor space.

The diet offered to both animals was identical. Nearly every day, the monitors were fed insects

Fig. 3. The second female (*V. panoptes horni*), photographed in October 2006, just a few days after hatching.

Figs. 4 & 5. The second female (*V. panoptes horni*) in an outdoor terrarium, April 2008.

(cockroaches, crickets, and *Zophobas* larvae). Once a week chicken hearts were offered, but before feeding the hearts, the fat was removed and the hearts were dusted with a vitamin and calcium supplement. Once a month the chicken hearts were substituted for a freshly killed sub-adult rat as a way of offering some variety to the diet. All insects were offered to the lizards outside their enclosures, which gave the animals 10-30 min to roam around the reptile room, which measured about 8 m^2. Only one lizard at a time was given free run outside its enclosure. The strategy here was to tame the animals during this time to make handling easier.

A 300 W Osram® Vitalux was installed in each enclosure to provide a source of UV. The lamps were switched on two or three times a week for ca. 30 - 45 minutes at a time. The temperature in the reptile room ranged from 25-30 °C between April and September, and 20-28 °C between October and March. Both enclosures were partially located under a window, which allowed natural sunlight into the enclosures (Fig. 6.). Each enclosure also featured a 100 x 50 cm area of floor space which was heated with a heating cable. A 75 W halogen spotlight and the Osram® Vitalux were positioned over this area to provide additional light, heat, and UV. A wooden box measuring 60 x 45 x 25 cm, half-filled with fine, dust-free and slightly dampened sand was also provided in the enclosures for refuge or egg laying.

Fig. 6. The second female in its terrarium.

Table 1. Clutch data for the initial female *V. panoptes*.

Date of oviposition	Clutch size	No. eggs incubated	Incubation period [d]	Remarks
21-22 Dec 2004	7	3	154 - 187	Two dead embryos with cranial malformations (no eyes, upper jaw shortened)
1 Apr 2005	5	2	-	Laid 101 days after previous clutch
15 Jun 2005	7	4	-	Laid 75 days after previous clutch
6-10 Sept 2005	6	-	-	Produced after female had sustained a spinal injury

Egg deposition by the first animal

The first female was approximately 23 months of age when it produced its first clutch. One month prior to laying, it measured 37 cm SVL and 86 cm TL, and weighed 1.18 kg. Data for clutches produced in 2004 and 2005 are listed in Table 1. One of the eggs laid between 21-22 December 2004 ruptured after 154 days of incubation, most likely due to an excessively wet incubation medium, and contained a partially developed embryo. The remaining egg from this clutch incubated for 187 days before beginning to deteriorate. Upon dissection, a deceased, but near fully-developed embryo was discovered. Both embryos showed similar cranial deformities (Fig. 7).

On 16 June 2005, this animal was found lying in the enclosure with what appeared to be a fractured spine. The location of the injury was just in front of the pelvic girdle, and veterinary examination confirmed a fractured spine. Over the next four weeks, daily injections with a nerve-stimulating drug (Thiamin) were administered into the base of the tail. After about six months, the monitor began to walk again in a reasonably coordinated manner. The cause of the injury remains unknown; however, the fact that this young female produced three clutches of eggs within a span of 200 days may have contributed to metabolic bone disease.

In 2006 and 2007, four more clutches of four to six eggs (two clutches per year) were produced. This female produced another clutch of four eggs in early August 2008, but then died unexpectedly one week later. Eggs from the clutches produced between 2006 and 2008 lacked any signs of viability.

Egg deposition by the second animal

The second female produced its first clutch at 32 months of age. One month prior to laying, it measured 44 cm SVL and ca. 100 cm TL, and had a body mass of 2.95 kg. This animal was clearly older and larger than

Fig. 7. This fully developed embryo came from the clutch of my first animal from December 22, 2004. Clearly visible are the absence of eyes and the shortened upper jaw.

Table 2. Clutch data for the second female *V. panoptes*.

Date of oviposition	Clutch size	No. eggs incubated	Incubation period (d)	Remarks
17 May 2009	11	4	174	One fully developed dead embryo with no visible malformations; egg yolk was not completely absorbed
27 Jul 2009	11	2	-	Laid 71 days after previous clutch; egg mass was 534 g
23 Aug 2009	9	2	196	Laid 27 days after previous clutch; egg mass was 484 g; 1 fully developed dead embryo with no visible malformations; egg yolk was not completely absorbed
3 Jul 2010	11	3	196 - 225	All eggs contained fully developed dead embryos with no visible malformations; egg yolks were not completely absorbed
8 Sep 2010	8	3	212*, 95 - 218	One live offspring hatched

* *incubation period for live hatchling*

the previous lizard at the time of its first clutch. Data for clutches produced in 2009 and 2010 are listed in Table 2.

Following the third clutch of 2009, which was laid only 27 days after the second, the husbandry of the female was modified. The amount of food offered was reduced from about 30 cockroaches a day to 5 to 15 crickets, cockroaches or giant mealworms per day. The female was also encouraged to chase these food items, which were offered from long forceps (Fig. 8). The animal had to chase the food until nearly reaching exhaustion. As soon as the monitor's effort in chasing the food decreased, the feeding was stopped. This was done in a manner to exercise the animal and enhance its physical fitness on daily basis. For subsequent clutches, only small rations of food were offered following egg laying. It was believed that this reduction in dietary intake following egg laying could increase the amount of time between subsequent clutches.

On 3 July 2010, a clutch of 10 eggs with a total mass of 543 g was laid (Fig. 11 & 12). Three of the eggs were white in color, turgid, and appeared fertile, weighing 67, 68, and 73 g, respectively. These eggs were transferred to an incubator, whereas the remaining seven did not appear to be viable and were discarded. An additional egg was found with the feces of the female on 9 July. All three eggs incubated for 196-225 days before they began to deteriorate. Upon dissection, it was discovered that each egg contained developed embryos which had died shortly before hatching.

On 8 September 2010, a second clutch of eight eggs was produced, weighing a total of 414 g. Shortly after producing this clutch, the female measured 50 cm SVL and 110 cm TL, and weighed 2.3 kg. Three eggs from this clutch (65, 64, and 63 g) appeared fertile and were transferred to the incubator. They initially developed well, but one egg began to deteriorate after 95 days. Upon opening this egg, a small embryo was visible. Egg number two began to sweat and was opened after 218 days. It contained a dead, fully developed embryo which still had a fairly large yolk sac remaining. After 212 days of incubation, the remaining egg hatched on 8 April 2011 (Fig. 13). The hatchling had a SVL of 12.0 cm, a TL of 27.5 cm, and a body mass of 29 g. A large yolk sac was still attached (Fig. 14). After 94 days, the juvenile had grown to 15.5 cm SVL and 37.5 cm TL, with a body mass of 88 g.

Incubation

Eggs were incubated in a commercially available BRUJA 3000/REP® incubator, where temperatures ranged from 28-29 °C. Vermiculite (medium grade), mixed equally with water by weight, was used as an incubation medium. Eggs were placed in individual 600 ml plastic containers and partially buried to approximately half their diameters. Six water channels within the incubator were kept filled during incubation

Fig. 8. To promote exercise, the second female *V. panoptes horni* was encouraged to chase food items offered from forceps.

Figs. 9 & 10. A dead, fully-developed embryo produced by the second female. No external abnormalities are visible.

Fig. 11. The second female shortly after egg deposition on 3 July 2010.

Fig. 12. Nine egg clutch produced by the second female on 3 July 2010. Three embryos developed, but died prior to hatching.

Fig. 13. Successfully hatched parthenogenetic *V. p. horni* on 8 April 2011.

Fig. 14. A large amount of residual yolk remained inside the egg following the hatchling's emergence.


Fig. 15. The parthenogenetic offspring seven days after hatching.


Fig. 16. The parthenogenetic offspring at the age of 50 days.


Fig. 17. The parthenogenetic offspring at 261 days old.

to help maintain a high level of humidity. Allowing the incubation medium to become too wet may have contributed to one egg bursting. Eggs that did not hatch became moldy, displayed flecks of discoloration, or collapsed.

There was clearly an increase in egg viability with both clutches produced in 2010. This may be the result of modifying the female's husbandry (reduced feeding and increasing physical exercise). Both embryos produced by the first female showed similar cranial deformities, whereas the seven fully-developed embryos from the second female had large residual yolk sacs.

Sex determination of four embryos

Three embryos from the 3 July 2010 clutch, and the fully developed embryo from the clutch laid on 8 September 2010 were stored in alcohol and subsequently dissected to verify their genders. These investigations, however, were inconclusive. Neither testicles nor ovaries could be positively identified within the abdomen, and none of the embryos displayed fully-everted hemipenes. Furthermore, the size and form of the hemipenal pouches at this stage of development were similar to those of hemiclitoral pouches, making sex determination not possible.

Parthenogenesis in the genus *Varanus*

Both female *V. panoptes* in this study did not have any contact with males after they were purchased, although the first animal was acquired as a subadult (ca. 8 months in age). According to Paden (2008), copulation has been observed in *V. panoptes horni* as young as 186 to 202 days old, with oviposition taking place just 23 days later. The female described in Paden (2008) had a SVL of 29.8 cm. The first female in the present study was purchased at an age of 245 days, but was only 20

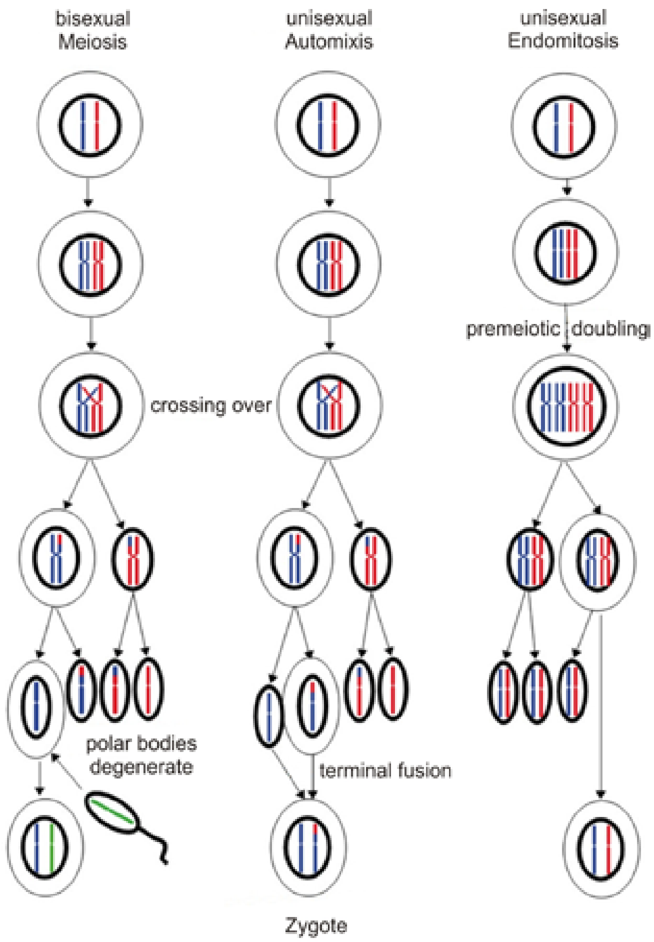

Fig. 18. Chromosomal development during sexual and asexual reproduction (after Lenk *et al*., 2005).

cm SVL. Given this smaller size and the fact that its first clutch was laid 463 days after purchase (on December 21, 2004), it is unlikely that copulation and sperm storage (amphigonia retardata) had occurred while at the pet shop. Therefore, it is likely that parthenogenesis was responsible for the development of both embryos produced by this female. Since the second female was only a few days old when purchased, parthenogenesis is also the most likely explanation for the development of embryos in eight of its eggs.

In recent years, reports of parthenogenesis in *V. panoptes horni* (Lenk *et al*., 2005), *V. komodoensis* (Watts *et al*., 2006), and *V. ornatus* (Hennessy, 2010) have been published. Several parthenogenetic *V. komodoensis* eggs were viable and actually hatched. A single offspring was reported for *V. panoptes horni*, whereas all *V. ornatus* embryos died within their eggs. Surviving offspring from Lenk *et al*. (2005) and Watts *et al*. (2006) were genetically examined, and the resulting data determined that the DNA from these hatchlings was not identical to that of their mothers. They were, however, very similar to the mother genetically, and all offspring were male. Genetic examinations have not been performed on the two parthenogenetic *V, ornatus* embryos described by Hennessey (2010) nor the ten potentially parthenogenetic *V. panoptes* specimens described in this article. All known cases of parthenogenesis in monitor lizards have occurred in captive situations where a male was not present. In only two reported cases have the same parthenogenic females also successfully reproduced sexually at a later date (Lenk *et al*., 2005; Watts *et al*., 2006).

Genetically examined parthenogenetic monitors have been found to be automictic with terminal fusion (Lenk *et al*., 2005; Watts *et al*., 2006). The most prevalent form of parthenogenesis in reptiles, however, is endomitosis (see Fig. 18). In endomitosis, the resulting offspring are all female and very similar to their mothers genetically. This form can be found in some populations of Gekkonidae, Teiidae and Lacertidae (e.g., *Darevskia "armeniaca"*), and is the most common form of propagation in these taxa (Lenk *et al*., 2005; Kearney *et al*., 2009). The observable breakdown of meiosis during endomitosis may be caused by the hybridization of closely related species (Kearney *et al*., 2009).

During automictic parthenogenesis, meiosis proceeds in a normal manner, which results in a haploid ovum capable of fertilization (Fig. 18). A diploid zygote forms through fusion with a polar body, which is generated during meiosis. Automixis is therefore a kind of self-fertilization, and it is possible that the absence of a male might induce this phenomenon (Lenk *et al*., 2005).

The male gender of the examined offspring might be explained by the type of sex chromosomes present in monitor lizards. King & King (1975) indicated that gender is genetically fixed in several species of *Varanus* and that this condition is very likely identical in all monitors. Many reptile and bird species lack the X- and Y-sex chromosomes seen in humans, and instead have a system of W- and Z-sex chromosomes in which females have WZ chromosomes and males have ZZ chromosomes. During automictic parthenogenesis with terminal fusion, both sex chromosomes originate from the female's chromosome set, and therefore only two variations are possible (WW or ZZ). Although zygotes with two W-chromosomes are not viable, zygotes with two Z-chromosomes can develop, producing males.

In 1952, two American agricultural researchers discovered that some level of development (*e.g.*, membranes, blood, embryos) occurred in about 17% of unfertilized turkey eggs, although larger embryos developed in only about 0.2% of eggs from the 1952 breeding season (Olsen & Marsden, 1953). Given this discovery, a breeding program was initiated to increase the occurrence of parthenogenesis in turkey eggs. By 1962, over 40% of incubated eggs showed some form of development, and well-developed embryos were seen in 13% of the eggs (Olsen, 1965). However, only 94 chicks hatched out of the 8,519 eggs incubated, and only 25% of these hatchlings survived. All chicks raised were males, because gender in turkeys is fixed by a WZ- sex chromosome system. Some of these offspring were even able to produce viable sperm. This example of parthenogenesis in turkeys can be applied to monitor lizards since the reproductive biology, fixation of gender, and relating matters are similar between birds and monitors as well as many other reptiles.

The costs of parthenogenesis

The main advantage of sexual reproduction is that it produces offspring with largely heterogenetic information which can better enable populations and species to adapt to changing environmental conditions. But sexual reproduction also has significant disadvantages. For instance, males, which in most cases are only sperm donors, are competitors with their own siblings, females, and offspring in the fight for resources (*e.g.*, territory, food). Offspring resulting from endomitosis, the most common form of parthenogenesis in reptiles, obtain their genetic information from their mother. Because the heterogeneity from one generation to the next will not decrease, this form of parthenogenesis can easily replace sexual propagation, and can be the predominant mode of reproduction for more than 100 generations (Kearney *et al*., 2009). Nevertheless, endomitosis is rarely found in nature. Since the genetic information will not change from one generation to the next, existing DNA-defects probably cannot be repaired (Archetti, 2004). Adaptation to abrupt environmental changes is also highly unlikely, because individuals from such a population have nearly identical gene pools.

Automixis is very rare among vertebrates, and this phenomenon has only been observed in some lizards, birds, and sharks under artificial conditions, where male animals were absent (Schuett *et al*., 1997; Olsen, 1965; Feldheim *et al*., 2010). Offspring resulting from this form of parthenogenesis only acquire genes from their mothers; therefore, the majority of these genes are homozygous. Harmful recessive mutations, which could be masked in the heterozygous condition, could become homozygous and operative. The decrease in fitness observed in turkeys (fertility, infection resistance, life expectancy, etc.), for example, also occurs with the inbreeding of mice after four to twelve generations (Bowman & Falconer, 1960). In the case of automixis, this decrease happens in just one step (Watts *et al*., 2006). Offspring mortality could be very high, as demonstrated in the above mentioned turkeys. It can be assumed that viable offspring resulting from automictic parthenogenesis may coincidentally have a reduced amount of harmful recessive mutations. This reduction of recessive and harmful mutations can be beneficial since it constitutes a purging of the genetic load (Crnokrak & Barrett, 2002). However, the negative impact of recessive mutations in large and heterogeneous populations is negligible.

Offspring resulting from a mating between a mother and one or more of her parthenogenetic sons can decrease the genetic diversity by 50–60% (Hedrick, 2007). This result could have a negative impact on the ability of small populations (*e.g.*, Komodo dragons) to adapt to changing environmental conditions.

Discussion

With automictic parthenogenesis documented in three different species of monitor lizard, it is possible that all female monitors possess this ability. Over the past several decades, this form of facultative parthenogenesis has been discovered in several different vertebrate groups (*i.e*., monitor lizards, rattlesnakes, garter snakes, turkeys, sharks), and it is possible that many other reptile genera possess this ability. Aside from long-term sperm storage, parthenogenesis could also explain the production of viable eggs or offspring when mating has not taken place in months, or even years.

The viability of automictic offspring appears to be significantly limited. The most important potential benefit of automictic parthenogenesis may be the ability to colonize new insular habitats, reached by unfertilized females. In the case of monitor lizards, such a female could produce a male companion for itself, or for other females arriving at the same location in the future, through parthenogenesis. Following this, normal sexual reproduction could increase the population size. The inevitable loss of genetic diversity could be compensated with more individuals migrating to this isolated population in the future. The ability to reproduce through automixis may be increased by target-oriented breeding programs. In contrast to *V. panoptes* or *V.*

ornatus, parthenogenetic offspring from *V. komodoensis* may have a higher viability. *Varanus komodoensis* may have used this form of reproduction in the past while populating other islands in its current distribution.

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Population Status of Two *Varanus* species (Reptilia: Sauria: Varanidae) in Sri Lanka's Puttalam Lagoon System, with Notes on their Diet and Conservation Status

D.M.S. Suranjan Karunarathna[1]*, A.A. Thasun Amarasinghe[2], Majintha B. Madawala[3] & H.K. Dushantha kandambi[1]

[1] *Nature Exploration & Education Team*
B-1/G-6, De Soysapura Flats
Moratuwa 10400, Sri Lanka
Email: dmsameera@gmail.com
*corresponding author

[2] *Komunitas Konservasi Alam Tanah Timur,*
Jl. Kuricang 18 Gd.9 No.47
Ciputat 15412, Tangerang, Indonesia
Email: thasun.thaprobanica@gmail.com

[3] *Young Zoologists' Association*
Department of National Zoological Gardens
Dehiwala 10350, Sri Lanka
Email: majintham@yahoo.com

Abstract - In Sri Lanka, varanid lizards (Genus: *Varanus*) are represented by only two species: *V. bengalensis* and *V. salvator*. During 46 days of field work in the Puttalam Lagoon system from 2008 to 2009, we recorded three *V. salvator* and 76 *V. bengalensis*. Of the *V. bengalensis*, 37 (48%) were males, 24 (32%) females and 15 (20%) juveniles. The male to female sex ratio of recorded specimens was 3:2. Most *V. bengalensis* were recorded from residential gardens and others from forested areas, while *V. salvator* were only recorded from forested areas. There is a local belief that eating the tongues of *V. bengalensis* increases memory capacity. Some villagers also extract an oily liquid from roasted *V. salvator* and consider it to be a deadly poison. We recorded 42 additional specimens of *V. bengalensis* killed on roads- most were hit during afternoon hours, as well as 26 individuals that were hunted. Current environmental threats and suggested conservation measures are also discussed.

Introduction

Sri Lanka harbors a rich biodiversity, which includes high herpetofaunal diversity (Bossuyt *et al*., 2004; Gunawardene *et al*., 2007; Meegaskumbura *et al*., 2002; Myers *et al*., 2000). There are 96 species of lizards native to Sri Lanka including 74 (77%) which are endemic to the island (de Silva, 2006; Somaweera & Somaweera, 2009). According to Koch *et al*. (2010), the genus *Varanus* Merrem, 1820 consists of 73 extant species (including 21 subspecies). Two species occur in Sri Lanka: *V. salvator* Laurenti, 1768 and *V. bengalensis* Daudin, 1802 (de Silva, 1996, 1998; Das, 2001; Deraniyagala, 1953; Smith, 1935). In Sri Lanka, *V. salvator* is distributed in areas below 500 m in elevation and *V. bengalensis* occurs up to 460 m elevation (Das & de Silva, 2005; Rathnayake, 2001; Whitaker & Whitaker, 1980), but outside of Sri Lanka, *V. salvator* is known to occur up to 1100 m (Erdelen, 1991) and *V. bengalensis* up to 1500 m (Auffenberg, 1994). Although both are

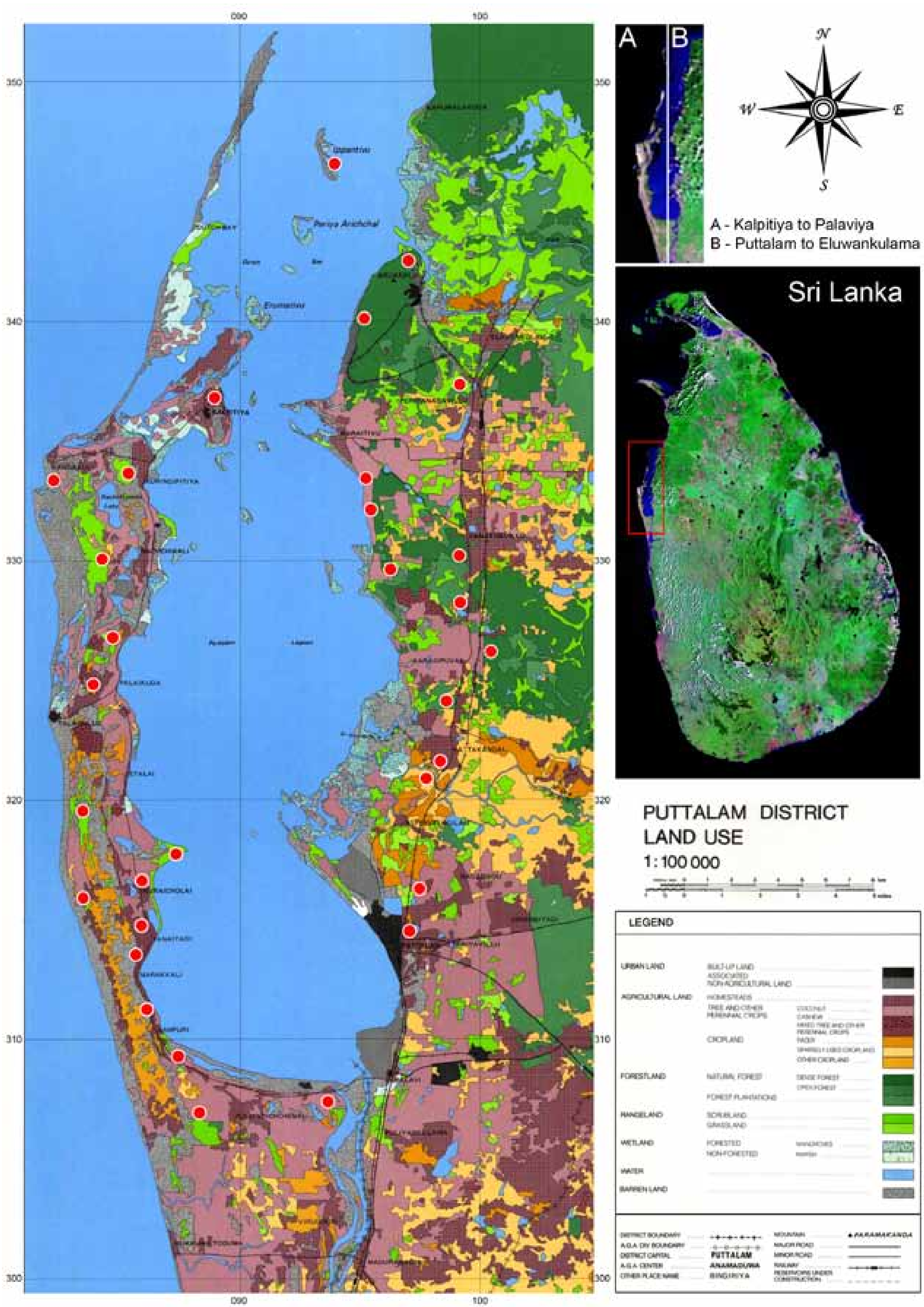

Fig. 1. Map of the 2008-2009 study areas in the Puttalam Lagoon system. Red dots indicate study points.

commonly encountered in anthropogenic habitats, *V. salvator* is semi-aquatic, whereas *V. bengalensis* is semi-arboreal. Both species are threatened due to various human activities (Amarasinghe *et al*., 2009; Daniel, 2002; Gaulke & de Silva, 1997). *Varanus salvator* has been heavily exploited for many decades by the reptile skin trade in Indonesia (Shine *et al*., 1998); *V. bengalensis* has been restricted from international trade under the Convention on International Trade in Endangered Species (CITES) since 1975.

One of the biggest challenges facing the conservation of varanids in Sri Lanka is a lack of information on their distribution and ecology since only a fraction of populations present in the country are hitherto known to science. Hence, it is essential to gather information on their distribution and ecology in different areas of the country as a first step towards their conservation. This article contributes new information to what is currently known about *V. salvator* and *V. bengalensis* within the Puttalam Lagoon system.

Materials and Methods

Surveys of the *V. salvator* and *V. bengalensis* populations in the Puttalam Lagoon system were conducted over 46 field days (Kalpitiya ~27 and Puttalam ~19) between November 2008 and October 2009. Observations were made by eye at a distance of 2 to 20 m between 0700 and 2000 h (sometime 8×40 binoculars were used). Varanids were primarily surveyed using the Visual Encounter Survey (VES) method (Magurran, 2004), but searching was also carried out in potential microhabitats such as beneath decaying logs and stones, and in tree holes and house roofs. Some specimens were captured for sex determination, examination of scale patterns, and for external measurements. These animals were photographed and released in the same habitat they were captured. External measurements were taken to the nearest 1 mm using a manual vernier caliper and a 1 m measuring tape. Egg measurements were also taken with a vernier caliper before carefully placing them back into their original nest hole. A thermometer and hygrometer were used to record temperatures and relative humidity during observations. Road kills and data on animals killed by villagers were also included as additional sources of information. We interviewed villagers using our own questionaire forms. Diagnostic keys and characters given by Daniel (2002), Das & de Silva (2005), Deraniyagala (1953), Smith (1935), Somaweera & Somaweera (2009) and Taylor (1953) were used for species identification.

Study area and Habitats

Puttalam Lagoon (study areas) runs through Eluwankulama to Kalpitiya (Fig. 1) over a road distance of ca. 80 km (8º 10 N and 79º 50 E) and is located in Puttalam District (Weerasinghe, 2008) (Fig. 2). The area ranges in elevation from 1-20 m above sea level, and has been characterized as dry and arid lowlands (Ashton *et al*., 1997). According to the floristic classifications of Gunatilleke & Gunatilleke (1990), the major vegetation types of this area include tropical dry mixed evergreen forests (*Manilkara* as well as mixed communities dominated by *Chloroxylon*, *Vita*, *Benya*, and *Schleichera*), tropical thorn forests (*Manilkara*, *Chloroxylon*, *Salvadora*, and *Randia* as dominant genera), Damana and Villu grasslands (Fig. 3; see Gunatilleke & Gunatilleke, 1990), flood-plain wetlands, riverine and gallery forests, and extensive mangrove habitats (Fig. 4). Forested areas are mainly composed of the trees Palu (*Mimosop hexandra*),

Fig. 2. Sand dune habitat in the Kalpitiya area.

Fig. 3. Grassland habitat around the Sethta Villu in Aruwakkalu.

Fig. 4. Mangrove habitat in Sevwanthive.

Fig. 5. Natural forest habitat in Eluwankulama.

Weera (*Drypetes sepiaria*) and Tammenna (*Mischodon zeylanicus*). Common shrub species found in the area are Nerenchi (*Acanthospermum hispidum*), Karamba (*Carissa spinarum*), Ranawara (*Cassia auriculata*), Wal kapu (*Ceiba pentandra*), Andara (*Dichroatachys cinerea*), Eraminiya (*Zizyphus rugosa*), Gandapana (*Lantana camara*), Mádan (*Syzygiun cumini*) and Podisingchomaran (*Eupatorium odoratum*) (Fig. 5). Introduced plants such as coconut palms (*Cocos nucifera*) and cashews (*Anacardium occidentale*) are also present.

The average annual rainfall is < 1100 mm, with most of the rain occurring during the months of November and December (Somasekaran, 1988). Occasional showers do occur at other times of the year, and the weather is driest between May and September. Highest temperatures were recorded during August (around 34.8 °C). The mean annual temperature in the Puttalam area is 29.6 °C, with a minimum of 25.4 °C.

Results

During 46 field days encompassing both dry and wet seasons, we recorded three sightings of *V. salvator* (all adults) and 76 of *V. bengalensis* (Fig. 6). One *V. salvator* was recorded from an isolated islet in Puttalam Lagoon near Kalpitiya; the other two locations were Eluwankulama and Vanatha-villuwa. We did not record any *V. salvator* from the area between Palaviya and mainland Kalpitiya. According to surveys conducted among villagers over 50 years in age (n=100), 80% of them had seen *V. salvator* only once in last 25 years, and the other 20% saw this lizard twice (Fig. 7). Sixty percent of villagers between the ages of 25-49 years

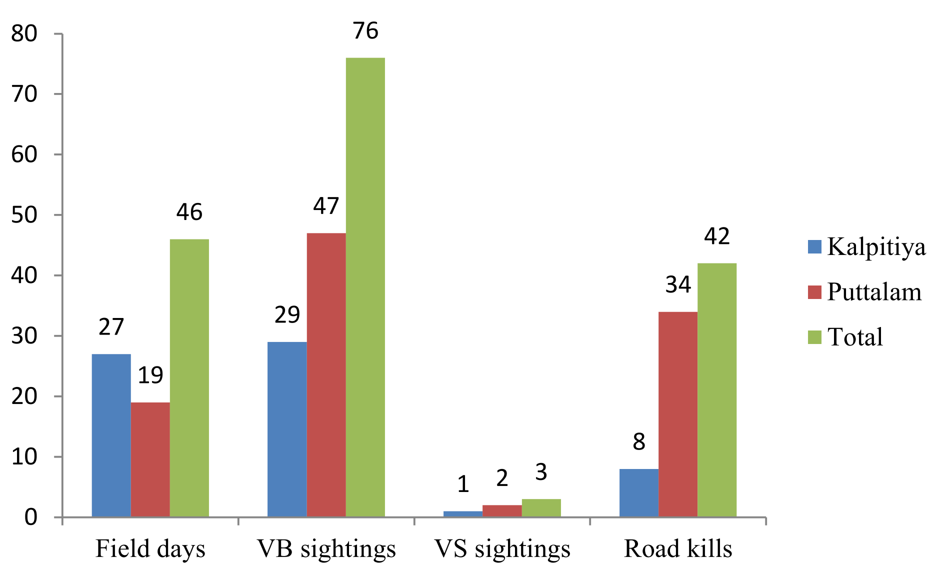

Fig. 6. Comparison of days and sightings of two *Varanus* species in the survey area (VB = *V. bengalensis* and VS = *V. salvator*).

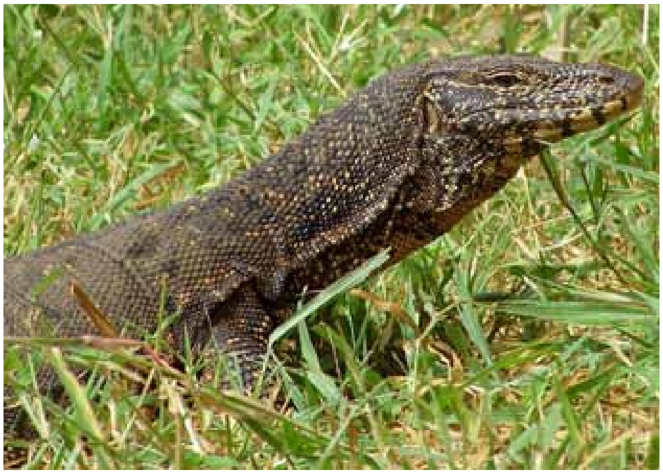

Fig. 7. Adult female *V. salvator* in grassland habitat.

Fig. 8. Foraging behavior of *V. salvator* in an aquatic habitat.

(*n*=200) had only seen *V. salvator* once in the last 10 years, whereas the other 40% hadn't seen the species at all. All villagers claim to have seen *V. bengalensis* more than 100 times in their lifetime, and 26% claim to have seen *V. bengalensis* nesting sites. There are many freshwater bodies in the area, with almost all occupied by crocodiles (*Crocodylus palustris*). Some villagers have observed *C. palustris* feeding on *V. salvator* about 10 years back.

According to villagers, the *V. salvator* in the area feed on cobras (*Naja naja*), rat snakes (*Ptyas mucosa*), keelbacks (*Xenochrophis* cf. *piscator*), peacock eggs and chicks, cormorants (*Phalacrocorax niger*), crows (*Corvus splendens*), black tortoises (*Melanochelys trijuga*), crabs, and shrews (*Suncus* sp.) (Fig. 8). During the course of study, we observed *V. salvator* feeding on kukri snakes (*Oligodon taeniolata*) as well as on fish, beef, pork and other discarded meat in the garbage. According to villagers, the main predators of juvenile and adult *V. salvator* are wild boars (*Sus scrofa*), which are very common in the area, and crocodiles (*C. palustris*). Wild boars especially feed on hatchlings and eggs. Some people do not like *V. salvator* and chase them on sight, throwing stones and sticks at them and sometimes killing them, but never eat their meat. However, skeletal remains of *V. salvator* found in the caves of Balangoda Man (35,000 to 40,000 BC) indicate that *V. salvator* was consumed by prehistoric inhabitants (Manamendra-Arachchi, pers. comm. 2011). No *V. salvator* road kills were recorded during the study period, nor did we observe any courtship or mating behaviors. There are many mythical beliefs about this species, and according to villagers aged over 50 years, *V. salvator* is a shy reptile and avoids humans. Two individuals were purportedly killed over the past few years.

The *V. bengalensis* population from Puttalam to Eluwankulama appears to be very large, with 47 sightings (males, 23; females, 15; juveniles 9) recorded from the Eluwankulama area (5:3 male-female sex ratio), and another 29 (males, 14; females, 9; juveniles 6) from the Kalpitiya area (3:2 male-female sex ratio). In total, 85% of *V. bengalensis* sightings were recorded from residential gardens, and the rest from forested areas. By contrast, all *V. salvator* sightings were recorded from forested areas. *Varanus bengalensis* were never recorded near lagoons, mangroves or any other aquatic habitats close to the lagoon. A large number of ectoparasites and endoparasites were recorded from both species (Fig.

Fig. 9. Ectoparasites on the tail base of *V. bengalensis*.

Fig. 10. Morning foraging behavior in a *V. bengalensis*.

9). Combat behavior between male *V. bengalensis* was infrequently observed during the months of August and September. Combat behavior mostly occurred when temperatures were between 30.2-33.5 °C, and humidity levels were between 68-73%.

The average snout to vent length (SVL) for adult male *V. bengalensis* was 422 ± 25 mm (range 388-474 mm) and 439 ± 14 mm (range 418-463 mm) for females. Average head length (HL) was 98 ± 8 mm (range 84-108 mm) in males and 104 ± 3 mm (range 99-108 mm) in females (*n*=12; see Table 1). Eggs of *V. bengalensis* averaged 45.5 ± 1.35 mm in length (range 42.6-47.4 mm) and 24.4 ± 0.61 mm in width (range 23.5-25.2 mm).

According to villagers, *V. bengalensis* feeds on agamid lizards (*Calotes versicor*, *Sitana ponticeriana*), crabs (*Oziothelphusa hippocastanum*), toads (*Duttaphrynus melanostictus*), juvenile tortoises (*Geochelone elegans*), juvenile freshwater turtles (*Lissemys ceylonensis*), small mammals (*Ratus ratus*), juvenile birds (house sparrows, chickens, lapwings, pigeons) and eggs, and bats (*Pipistrellus* sp.). During this study, we also observed *V. bengalensis* feeding on frogs (*Euphlictis hexadactylus*, *E. caynaphlictis*, *Hoplobatrachus crasus*, *Hylarana gracilis*), tree frogs (*Polypedatus maculates*), snakes (*Calliophis melanurus*, *Amphiesma stolata*, *Lycodon striatus*, *Rhinophis* sp.), earth worms (Fig. 10), centipedes, dung beetles, and juvenile chameleons (*Chamaeleo zeylanicus*). From the undigested gut contents of road killed specimens, we recorded additional prey items including snakes (*Ptyas mucosa*, *Oligodon arnensis*), skinks (*Europis carinata*, *E. tammanna*), geckos (*Hemidactylus leschinaulti*), and land snails (*Achatina fulica*).

Table 1. External body measurements of mature *Varanus bengalessis* in Puttalam area (*n*=12). Abbreviations: SVL = snout to vent length; HL = head length.

ID No.	Males (mm)		Females (mm)	
	SVL	HL	SVL	HL
01	391	85	426	101
02	413	98	453	107
03	427	102	432	104
04	398	88	447	106
05	442	105	463	108
06	405	91	428	102
07	432	103	425	103
08	388	84	436	104
09	451	106	418	99
10	418	99	446	106
11	426	102	457	108
12	474	108	442	104

Humans are the primary predator of adult and juvenile *V. bengalensis*, but according to villagers other predators include changeable hawk-eagles (*Spizaetus cirrhatus*), pythons (*Python molurus*), peacocks (*Pavo cristatus*), Sri Lankan grey hornbills (*Ocyceros gingalensis*) and white-bellied sea-eagles (*Haliaeetus leucogaster*). Egg predators include wild boars (*Sus scrofa*), rat snakes (*Ptyas mucosa*), domestic cats (*Felis cattus*), and dogs (*Canis familiaris*). During the study period, we observed 42 road kills (41 juveniles and 1 adult) and 26 individuals hunted by humans (9 juveniles and 17 adults).

We found two *V. bengalensis* nests comprised of 8 and 11 eggs located in the bottoms of abandoned termite mounds (Fig. 11). Nest temperatures and humidity levels for these clutches were 30.6 °C and 69%, and 31.2 °C and 62%, respectively. At the time of their discovery, these mounds were also being utilized by cobras and vipers. Walikanna & Karunarathna (2009) also noted that termite mounds in Sri Lanka were utilized by cobras

Table 2. Measurements of *V. bengalesis* eggs (*n*=10) in two locations (Abbreviations: EL = egg length; EW = egg width; SD = standard deviation).

	Thirikkapallama August					Vanathavilluwa October					
	1	2	3	4	5	6	7	8	9	10	Mean ± SD
EL (mm)	45.7	46.3	45.7	45.8	47.4	46.3	43.9	45.6	46.1	42.6	45.5 ± 1.35
EW (mm)	23.5	24.8	25.2	24.6	24.7	24.6	23.6	24.2	25.1	23.8	24.4 ± 0.61

(*Naja naja*) as well as skinks (*Eutropis carinatus*). All eggs were deposited in holes inside termite mounds with good air circulation and in areas of minimal human disturbance. The nesting substrate was not packed down by the female after egg deposition (Table 2). We did not observe juveniles emerging from eggs, but were able to locate newly hatched juveniles in human habitations (*i.e.*, on roofs, in kitchens, etc.). Juveniles live mostly in areas 3-5 m above the ground, especially on trees, walls and electric pillars (Fig. 12); Deraniyagala (1953) reported similar behavior.

Forty-one road-killed juvenile *V. bengalensis* in the size range of 218 to 283 mm SVL (*n*=41), and only one adult road kill (462 mm SVL) were recorded. This is an interesting record, because more than 97% of road kills were juveniles (Fig. 13). This may be due to their activity period and foraging patterns, as most were killed in the afternoon (1100 to 1500 h). Road killed specimens were mostly recorded when temperatures were between 29.8-32.6 °C and humidity levels were between 55-74%. According to published records including Auffenberg (1986), Cota (2011), Wikramanayake (1995) and Wikramanayake & Green (1989), *V. bengalensis* tend to move and forage in the afternoons. Varanids are primarily diurnal and are usually active between 0700-1700 h (Jolley & Meek, 2006; Meek, 1978; Wickramanayake, 1995; Wikramanayake & Dryden, 1993), but we observed one *V. salvator* active at 1840 h and four *V. bengalensis* active between 1725 and 1855 h.

Fig. 11. Adult male *V. bengalensis* emerging from a termite mound.

Discussion

The narrow area between Palaviya and Kalpitiya is mostly dry with sandy earth, but there are also mangrove habitats. While a small population of *V. bengalensis* (*n*=29) was recorded from this area, *V. salvator* was not observed. There are also no records of *V. salvator* occurring in this area over the last 25 years, and before that, only one record exists. The only individual we recorded was from Ippantivu Islet in Puttalam Lagoon, situated 2.2 km from the mainland (Fig. 14). In Sri Lanka, this is the greatest distance that *V. salvator* has been recorded from the mainland, even though there are many records of this species swimming between islands in Indonesia (Borden, 2007; De Lisle, 2007). Although similar in habitat to Potuvil Lagoon (North-eastern province), the *V. salvator* population in the Puttlam Lagoon system appears to be considerably lower. We also failed to record any *V. salvator* from lagoons around Panama, although they were present near inland water holes (Somaweera *et al*., 2004). In southern parts of Sri Lanka (*e.g*., Rath-ganga, Benthota-ganga, Madu-ganga and Kalu-ganga), *V. salvator* was very common close to river mouths.

According to published accounts, interviews with fishing communities, and personal observations, there

Fig. 12. Juvenile *V. bengalensis* found in a village house in Thirikkapallama.

Fig. 13. A road killed juvenile *V. bengalensis* in Vanathavilluwa.

does not appear to have been migrations of *V. salvator* between Sri Lanka and India in the past 50 years. Therefore, Sri Lanka populations may be isolated from other *V. salvator* populations found in northeastern India and the Nicobar and Andaman islands (Koch *et al*., 2007). In Puttalam Lagoon, they have the ability to migrate over short distances between more than 10 islands. A similar occurrence was documented by De Lisle (2007) in North Sulawesi. Even though there is suitable habitat and an abundance of food (*i.e.,* excess fish, discarded meat and garbage) around Puttalam Lagoon, the *V. salvator* population is very low and would be interesting to investigate. Both *V. salvator* and *V. bengalensis* have been known to eat boiled rice and cooked foods, and according to published accounts, *V. salvator* are known to live around garbage dumps and polluted areas in Sri Lanka, as well as Indonesia (Das & de Silva, 2005; Karunarathna *et al*., 2008a; Shine, 1986; Somaweera & Somaweera, 2009; Uyeda, 2009). Both species are valuable as pest control agents in these areas (de Silva, 2006; Deraniyagala, 1953; Rathnayake, 2001).

Varanus bengalensis and *V. salvator* are also valuable to tourism in Sri Lanka, as many foreigners enjoy watching them and their behaviors (Gramentz, 2008, 2010). Unfortunately, we have noticed numerous tour guides including many naturalists introduce them as iguanas. In the areas of Bentota, Kalutara and Galle we observed many foreigners photographing these lizards, but we have also observed many road-killed *V. bengalensis*, including some killed by DWC vehicles and hired jeeps, inside Udawalawa, Yala, Wilpattu, Kumana and Maduru-oya National Parks between 2010 and 2012.

Varanid lizards are also an important feature in local art, and both species have a place in folklore and are closely associated with the day to day life of humans. They are subjects of many stories and poems in Sinhala literature. The following village poems mention both species of *Varanus* in Sri Lanka. In the poems below, 'kabaragoya' refers to *V. salvator*, and 'thalagoi patiya' refers to a juvenile *V. bengalensis* (*thalagoya* = land monitor; *thalagoi* = land monitor's; *patiya* = infant).

(1) *Tikiri Tikiri Tikiri liyà*
[Young woman]
Käleth aran lindata giyà
[Went to the well (to take water) with a pot]
Linda watakara kabaragoyà
[There was a water monitor circling the well]
Käkula käpi diya bariya
[Its leg was bitten by a keelback snake]

(2) *Mä-Bälë athi kala thalagoi patiyà*
[The baby land monitor kept as a pet when I was a kid]
Mata thaniwata midulë pem kelimin sitiyà
[Was playing with me in front of the house, because I was alone]
Ugé maruwä awidin u aregena giyäsatiyà
[Death came and took him away]
Niwan purë palayan thalagoi patiyà
[Go to heaven, baby land monitor]

(Source: Education Department, 2006; Mahendra, 2000; Chandana & Liyanage, 1992)

Although people do not eat *V. salvator* flesh because

Fig. 14. One of the small islands located in Puttalam Lagoon.

there is a mythical belief that it is poisonous, we observed some villagers that killed a *V. salvator* and hung it by the tail. A fire was lit underneath it to help collect oily liquid secretions from the body. The liquid is then mixed with their enemies' alcoholic drinks. Many villagers told stories of how some people had died after drinking alcohol laced with this liquid. Some people also believe that if *V. salvator* scat is applied to a wound it will fester and require amputation, so this has compelled people to kill *V. salvator*. Many people eat *V. bengalensis*. To kill the animals when hunted, they are swung by the tail and struck on a hard surface. There is also a mythical belief that if *V. bengalensis* tongues are eaten, and individual's memory capacity will be increased. *Varanus bengalensis* are occasionally caught in noose traps (Fig. 15). According to Subramanean & Reddy (2012), there has recently been an increase in demand for its flesh in India, especially the tongue, due to the belief that it has curative properties for AIDS.

Conservation

Surprisingly, *V. bengalensis* has been assessed as a species of least concern by the IUCN Red List Category in 2011. Though it is currently listed as safe, further research and monitoring of this species is needed to ensure that the species does not become threatened in the future (*e.g.*, Subramanean & Reddy, 2012). In Sri Lanka, both *V. bengalensis* and *V. salvator* are protected under the Flora and Fauna Protection Ordinance (FFPO) (de Silva, 1998), and *V. bengalensis* is listed in CITES Appendix 1 (Somaweera & Somaweera, 2009). However, there is no management plan of the Forest Department (FD) or Department of Wildlife Conservation (DWC) for this species to reduce its threats.

In 2009, the areas between Kalpitiya and Palaviya, and between Puttalam and Eluwankulama were designated as tourism zones. This project has been helpful for increasing tourism revenue in Sri Lanka, but thousands of hectares of mangroves and natural forests continue to be cleared for development projects (Fig. 16). Additionally, more than 1000 hectares of mangroves and inland dry zone forest (mainly scrub) had been cleared for prawn cultivation and salterns between 1990 and 2005 (Weerasinghe, 2008). Presently, these areas have been abandoned due to the poor management and monoculture of the prawn farms.

Limestone extractions in the area are causing natural bodies of water to fill with mud as well as various other environmental problems (see Kumarasinghe *et al*., 2010; Karunarathna *et al*., 2009 for further details on environmental issues of this area). The DWC and relevant authorities should especially take responsibility for these issues, and implement relocation and conservation programs to parallel governmental development programs. Education and awareness programs should focus on villages, school students and the general public, and universities should use these areas for research and experimental programs. Art, photography, writing, and debate competitions should be introduced to the general public through child scout groups as well as "*Parisara Niyamu Bata Kandayam*" in the Central Environmental Authority (CEA). Together with customs, the DWC should monitor any international trade in these Sri Lankan *Varanus* species, especially since *V*. *salvator* has been heavily exploited for several decades by the reptile skin industry in several Asian countries (Gaulke, 1992; Shine *et al*. 1996, 1998).

Fig. 15. Adult *V. bengalensis* caught in a noose trap.

Finally, we conclude that further ecological and behavioral research is needed to help conserve Sri Lanka's monitor lizards and other faunal groups, and it is our own responsibility to conserve these species before they become just a legend in history.

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Fig. 16. Forest clearance in Eluwankulama which has been put up for sale.

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Predation of an Adult Malaysian Water monitor *Varanus salvator macromaculatus* by an Estuarine Crocodile *Crocodylus porosus*

Marcus Ng[1] and Robert W. Mendyk[2,3]

[1] E-mail: thebudak@gmail.com

[2] *Center for Science Teaching Learning and Learning*
1 Tanglewood Road
Rockville Centre, New York 11570, USA

[3] *Center for Herpetological Education and Inquiry*
P.O. Box 331
Mineola, New York 11501, USA
E-mail: odatriad@yahoo.com

Abstract - There are few published accounts which document predation of large adult monitor lizards. Here, we describe an observed case of predation on an adult Malaysian water monitor *Varanus salvator macromaculatus* by an estuarine crocodile *Crocodylus porosus* in Singapore. Estuarine crocodiles may represent the only significant predators of adult water monitors in coastal mangrove environments throughout their range.

Introduction

Widely distributed throughout Southern and Southeast Asia and the Indo-pacific, Asian water monitors belonging to the *Varanus salvator* species complex are large lizards, reaching total lengths (TL) of up to 3.2 m (Randow, 1932), but usually ranging between 1.4 and 2.3 m as adults (Gaulke & Horn, 2004; Horn & Gaulke, 2004). Some natural predators of *V. salvator* have been identified (e.g., Twedie, 1954; De Lisle, 2008), but very few have specifically documented predation on larger adult individuals (Goldthorpe *et al*., 2010; Siler *et al*., 2011). In this brief communication, we describe a case of predation on an adult *V. salvator macromaculatus* by a saltwater crocodile, *Crocodylus porosus* observed at Sungei Buloh Wetland Reserve, Singapore.

Study Site

Sungei Buloh Wetland Reserve is a 130 hectare coastal reserve located in northwestern Singapore. The reserve is largely dominated by mangroves and mudflats formed by the bunds of former prawn ponds, with a rear fringe of freshwater ponds and marshes. Public pathways provide direct access to some of these areas for wildlife viewing and photography.

Apart from serving as a vital stopover point for migratory birds along the East Asian-Australasian flyway, the reserve is a refuge for many locally threatened species such as smooth coated otters, shore pit vipers, and mud lobsters. Since at least 2005 (M.N., pers. obs.), estuarine crocodiles, *C. porosus*, have been regularly spotted in Sungei Buloh Besar- the main waterway running through the reserve which empties into the Straits of Johor, particularly during rising tides. It is unclear, though, whether these animals originate from swamps across the straits or are escapees from nearby crocodile farms.

A large and conspicuous population of *V. salvator macromaculatus* is present at Sungei Buloh Wetland Reserve (e.g., Rashid, 2004; Rashid & Diong, 1999; Kiat, 2007). Despite heavy human foot traffic, monitors are frequently observed in the reserve's mangroves and waterways including Sungei Buloh Besar, along pathways, and around the reserve's visitor's center.

Fig. 1. Sub-adult *Varanus salvator macromaculatus* basking alongside a pathway at Sungei Buloh Wetlands Reserve. Photograph by **Robert W. Mendyk.**

Fig. 2. Juvenile *V. salvator macromaculatus* in a tree hollow at Sungei Buloh Wetlands Reserve. Photograph by **Robert W. Mendyk**

Specimens of all size classes can usually be seen during a single day's visit, with sub-adults and adults reaching 2-2.5 m in total length (TL) usually basking and foraging in open areas and waterways (Fig. 1), and hatchlings and juveniles seeking refuge in, and peering out from tree hollows and crevices (Fig. 2).

Observations

While visiting the reserve for general nature photography, a predation event involving an estuarine crocodile and a water monitor was observed by the senior author and several companions on 15 January 2011 (Fig. 3). A commotion was heard in the water below the pedestrian bridge that spans Sungei Buloh Besar around 1220 h, which turned out to be a *C. porosus* (ca. 2.8-3 m TL) with a *V. salvator macromaculatus* (ca. 1.2- 1.5 m TL) in its jaws, located about 2 m from the riverbank. The initial attack was not witnessed, but it is likely that the crocodile had seized the lizard as the latter foraged close to the shore or in the water.

The crocodile had the upper torso of the monitor seized in its jaws, while it futilely attempted to lash its tail against the crocodile and use its rear limbs to free itself. For the next 10-15 min, the crocodile did not move much, apart from submerging itself every other minute, while the lizard struggled to keep its head above water. After submerging and then disappearing from sight, it resurfaced about 20-25 m upstream from the bridge. Here, it began to process its catch, raising its head and using its jaws to manoeuvre the lizard until it had a grip on its lower torso. At this point the lizard was still very much alive, though it had stopped struggling much and severe wounds and exposed viscera could be seen whenever it was lifted in the air. The crocodile then began to violently thrash the lizard by raising its head and upper body in the air before twisting around rapidly. It repeated this motion every few minutes until it had the lizard's head in its grip and there was no visible fight left in it. When a second, smaller crocodile surfaced nearby, the larger animal submerged itself and was not seen again. Consumption of the lizard was not observed. Total observation time was ca. 45 min.

Discussion

Water monitors of the *V. salvator* species complex and estuarine crocodiles co-occur in many coastal areas of Southeast Asia and the Indo-pacific. Considering that *C. porosus* is an opportunistic predator capable of taking large prey, it is not surprising that *V. salvator*, including adult individuals, fall victim to crocodiles in coastal environments. Although reticulated pythons, *Python reticulatus* (De Lisle, 2007), king cobras, *Ophiophagus hannah* (Siler *et al*., 2011), and smooth coated otters, *Lutrogale perspicillata* (Goldthorpe *et al*., 2010) are

Fig. 3. Estuarine crocodile (*Crocodylus porosus*) predation on an adult *Varanus salvator macromaculatus* in Sungei Buloh Wetlands Reserve, Singapore. Photographs by **Marcus Ng**.

known to prey on adult water monitors, *C. porosus* may represent the only significant predator aside from humans that is capable of taking adult *V. salvator* in coastal mangrove environments, and may therefore play a significant role in limiting their population sizes in these areas.

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Husbandry and Reproduction of *Varanus olivaceus* Hallowell (Sauria:Varanidae) at the Avilon Montalban Zoological Park

Matthew D. Yuyek[1,2]

[1]*Department of Herpetology and Arachnology*
Avilon Montalban Zoological Park
Barrio San Isidro, Rodriguez, Rizal, Philippines

[2]*Unit 32, Facilities Centre, 548 Shaw Boulevard, Mandaluyong City, Philippines.*
E-mail: matthewdyuyek@yahoo.com

Abstract - A facility for the captive breeding of *Varanus olivaceus* Hallowell, 1857, was established at the Avilon Montalban Zoological Park, Rodriguez (Montalban) Municipality, Rizal Province, Philippines in 1994. Reproductive husbandry and behavior of captive wild-caught adults were observed. A total of five clutches of eggs ranging from 4-16 eggs per clutch were produced by three females of variable sizes, between July and September of 2002-2005. All clutches were artificially incubated. The incubation period for a late-term neonate that expired shortly after being assisted with hatching was 209 days, and 217 days for a surviving, assist-hatched neonate. Feeding techniques and behaviors observed in both the wild-caught adults and the surviving captive-bred neonate are discussed.

Introduction

Of the three currently recognized species of large frugivorous monitor lizards endemic to lowland forests of the Philippines, namely *Varanus olivaceus* of Southern Luzon (Auffenberg, 1988), Catanduanes Island (Ross and Gonzales, 1992), and Polillo Island (Bennett and Hampson, 2003); *V. mabitang* of Panay Island (Gaulke and Curio, 2001; Gaulke et al, 2005); and, the recently described *V. bitatawa* of central and northern Sierra Madre mountain range in northern Luzon (Welton *et al.*, 2010), *V. olivaceus* is hitherto the only species that has been studied extensively, both in the wild and in captivity.

The earliest known captive populations of *V. olivaceus* were those maintained at the research camp of Walter Auffenberg in Caramoan Peninsula, Camarines Sur Province, Luzon, during his final phase of study on *V. olivaceus* from 1982-1983, and outside of the Philippines, those at the Florida State Museum and the Dallas Zoo (Auffenberg, 1988). In 1989, an adult individual of unknown gender was exhibited for the first time at the Manila Zoological and Botanical Garden, City of Manila. This species, known locally as *butaan*, has been observed being sold in pet shops around Manila (D. Bennett, pers. comm.), and has also been kept as pets in private collections inside and outside of the Philippines; unfortunately, most of these captives have perished due to maladaptation to captivity and flawed husbandry.

Published accounts of successful captive breeding in *V. olivaceus* are scant. Between 1984 and 1985, three clutches of nonviable eggs were produced by two females at the Bronx Zoo (Mendyk, in press). The Dallas Zoo was eventually able to produce a single F1 neonate in 1992, but the animal expired shortly after hatching (Card, 1995); death might have been caused by a congenital heart deficiency (W. Card, pers. comm.). Twelve years later, two F1 neonates were produced at the Avilon Montalban Zoological Park, of which only one has survived (now 7 years old at the Avilon Zoo). An article on the captive breeding and rearing of *V. olivaceus* at the Paradise Reptile Zoo in Puerto Galera, Oriental Mindoro Province (Lutz, 2006) is under critical discussion among specialists, and therefore will not be further dealt upon in this report.

Table 1. Morphometric data for *Varanus olivaceus* at Avilon Zoo taken on the day of arrival, 1994-2004.

Year	Locality	No.	Age Class	Sex	SVL (cm)	TL (cm)	ToL (cm)	WT (kg)	Remarks
1994	Bicol Peninsula	1	A	M	120.0	135.2	256.2	12.5	†●■◊
		2	SA	?	42.2	76.6	118.8	2.5	
		3	A	F	54.4	90.0	133.0	5.4	◊
		4	A	F	50.2	89.2	123.4	3.2	
		5	SA	?	44.2	76.3	120.5	3.0	†
		6	SA	?	46.8	80.0	126.8	3.2	□
1998	Bicol Peninsula	7	A	M	70.2	103.2	173.4	7.8	◊
		8	A	F	49.6	88.5	138.1	3.1	
		9	A	M	72.0	105.8	177.8	8.6	
		10	SA	?	44.7	67.4	112.1	3.2	†
		11	A	F	55.6	90.3	145.9	4.2	
		12	A	F	56.2	91.6	147.8	4.5	◊
2001	Cantanduanes Isl.	13	SA	?	43.5	76.0	119.5	2.5	
		14	SA	?	45.2	78.4	123.6	2.3	†
		15	SA	M	58.3	98.5	156.8	4.0	
		16	SA	F	44.6	78.2	122.8	2.8	†
		17	SA	F	46.5	80.9	127.4	2.6	
2004	Bulacan Province	18	A	M	71.0	105.0	176.0	8.0	†○◊

Symbols: † – tail tip missing; ● – 1st, 3rd, 4th, 5th digits of left fore foot missing; ■ – 4th, 5th digit of right fore foot missing; ○ – 2nd digit of left fore foot missing; □ – 5th digit of right hind foot missing; ◊ – prominent scars on head and dorsum.

This article reports on the captive management and breeding of *V. olivaceus* including the husbandry and reproductive behavior of captive adults as well as the successful hatching and post-neonatal care of the world's only surviving captive-bred *V. olivaceus*. A study on feeding, rearing, and growth rate of the neonate will be discussed in a forthcoming report.

Materials and Methods

Eighteen wild-caught *V. olivaceus* consisting of nine adults (4 males, 5 females), and nine sub-adults (1 male, 2 females, 6 unsexed) were acquired from reptile dealers for captive-breeding purposes by the Avilon Zoo between 1994 and 2004. Of these, twelve were from the Bicol Peninsula, five of Catanduanes Island origin (R. Ramos & M. Domingo, pers. comm.), and one from Norzagaray Municipality, Bulacan Province (J. Gaw *et al*., pers. comm.). Measurements were taken shortly after their arrival (Table 1) using a vernier caliper for head length and width, a retractable steel tape measure for snout-vent (SVL) and tail lengths (TL), and a household weighing scale for bodyweight. Sex was determined by the following methods: (1) hemipeneal probing using stainless steel probes; (2) manual eversion of the hemipenes; (3) hemipeneal extrusion whilst being restrained; and (4) visual comparison of tail base thickness. For identification, each individual was marked by notching the tail crests with a sharp stencil cutter (see Bennett, 2005).

Housing

The 1994 breeding stock (1 male, 2 females, 3 unsexed) was temporarily held at the Hexagonal Aviary while awaiting completion of the enclosures designed specifically for the keeping and breeding of monitor lizards. In 1994, the Hexagonal Aviary comprised a large, circular, central enclosure circumscribed by 11 smaller enclosures situated at each angle of the structure. Of these, nine were occupied by parrots, raptors, hornbills, pigeons, water fowl, and three species of mammal: Palawan bear cats (*Arctictis whitei*), palm civets (*Paradoxurus hermaphroditus*), and Malay civets (*Vivera tangalunga*). Two of these enclosures measuring ca. 1.5 x 1.2 x 3.6 m (l x w x h) were allocated for housing *V. olivaceus,* with one male and two females grouped together in each enclosure according to size and maturity.

The two enclosures were fitted with panels of narrow-slotted steel mesh on all sides but the rear wall. Since these enclosures were not designed for housing reptiles, the entire roof of each enclosure was covered with .4 mm thick pre-painted galvanized iron sheeting. Shallow rectangular wading pools made of concrete were constructed against the rear concrete wall of each enclosure. The clay soil in the enclosures was backfilled with a layer of coarse fluvial sand to a depth of ca. 10 cm. A service door, also made of narrow-slotted steel mesh was constructed at the rear of each enclosure and was accessible only from within the central enclosure. Tree branches were installed at various heights to facilitate climbing and basking, and two concrete drainage pipes large enough for the lizards to squeeze into were provided as retreats.

Large, portable steel cages reinforced with poultry netting were used to temporarily confine individual *V. olivaceus* of the 1998 breeding stock (2 males, 2 females) whilst large, rectangular, outdoor enclosures at the west perimeter wall of the zoo were being constructed. Similar to the enclosures in the Hexagonal Aviary, these enclosures, with an average measurement of ca. 4.5 x 1.5 x 2.5 m (l x w x h), were constructed with heavy-duty, narrow-slotted steel matting. A dug-out concrete pond ca. 35 x 20 x 15 cm (l x w x d) with a cemented rim and a drainage system was installed in each enclosure to facilitate functional waste water disposal. A ca. 10 cm deep layer of fluvial sand was laid over the clay soil. The steel mesh roof was partially covered with panels of pre-painted galvanized sheet to provide shade during midday. Climbing facilities were similar to those in the aviary, and a large hollow log was placed horizontally on the floor to provide refuge. For smaller *V. olivaceus* kept inside the Herpetarium, portable steel cages with tree branches and wooden hide boxes were utilized as holding cages.

The elevated monitor lizard exhibit enclosures that were specifically designed to simulate the natural habitat of monitor lizards varied from one to the other (Fig. 1). The enclosure where breeding took place in 2003 measured 3.0 x 2.0 x 2.0 m (l x w x h). A wading pool 37.5 x 22.5 x 15 cm (l x w x d) was built in the center of the enclosure. The substrate was composed of a 3:1 mixture of coarse fluvial sand and fine-grade coco

Fig. 1. Elevated monitor lizard exhibits at the Avilon Zoo.

peat filled to a depth of 15 cm. A drainage system was installed behind the enclosures. Artificial boulders and tree branches made of cement were strategically placed to facilitate climbing, and shallow caverns and ledges were constructed to serve as tight-fitting retreats and basking sites. The roof, also made of heavy duty steel mesh, was reinforced with 2.5 cm2 of chicken wire and partially covered with thick, transparent polyethylene sheeting to keep excessive rainwater from flooding the interior of the enclosure and to allow access to natural sunlight. The front of the enclosure was fitted with a panel of tempered glass (ca. 1.9 cm thick) to facilitate observation without visual barriers.

Individuals from Catanduanes Island were kept separate from those from the Bicol Peninsula, and were identifiable by their atypical ash-grey coloration (for comparison, see Fig. 2). Individuals purported to have been collected from evergreen forests of the Bicol Peninsula (n=13) exhibited a pronounced olive-green coloration whilst those from limestone forests of Catanduanes Island (n=5) surprisingly were distinctly ash-grey in coloration. Variation in body coloration within species corresponding to color differences in habitat strata has also been observed in *V. exanthematicus*, where individuals inhabiting dark soils of the coastal plain of Ghana tend to be darker in coloration than those inhabiting lighter soils in Agomeda (Bennett & Thakoordyal, 2003). Gaulke (1991) also mentioned differences in the coloration of *V. nuchalis* between animals from Negros and Panay Islands, and darker individuals from the islands of Masbate, Ticao, and Boracay. These color differences, however, are not attributed to the color of the substratum in their habitat, but rather the influence of geography. The variation in color between *V. olivaceus* populations requires further study.

Fig. 2. Color comparison between a Catanduanes Island *V. olivaceus* (left) and a specimen from the Bicol Peninsula (right). Note the ashy-grey coloration of the Catanduanes Island specimen.

Diet of captive adults

Feeding was initiated three days after the arrival of specimens. Food was offered once every 2-3 days between 0900 and 1000 h, after the lizards had basked.

Chicken heads were stored in a freezer and then thawed to room temperature before feeding. These were apportioned to each individual (ca. 100-150 g per feeding) and offered in a large plastic basin. All uneaten foods were removed after 1500 h.

Apart from chicken heads, rodents such as laboratory mice (*Mus musculus*), fancy rats (*Rattus norvegicus*), and wild-caught Luzon field rats (*R. argentiventer*) were fed once or twice a month as supplementary items. Because *M. musculus* and *R. norvegicus* had to be purchased from commercial breeders, only about 5% of those purchased were given to *V. olivaceus*, with the remaining 95% allocated to 112 snakes of 50 species maintained at the Herpetarium during early operations of the zoo. The rodents were stunned before being fed to the lizards either in a plastic basin or by tease-feeding using 62 cm long stainless steel hemostats.

Daily cleaning of enclosures was usually carried out in the morning before feeding time. The water in the pool was replenished daily; more often so if contaminated with feces or uneaten food. The top layer of the substrate was periodically scraped off and replenished with fresh material.

Egg incubation

All clutches of eggs were laid in the evening and collected the following morning. Misshapen eggs and those submerged in the pool were discarded. Eggs were marked and numbered with pencil to maintain the same polarity as when they were laid. The eggs were measured (Table 2) with a vernier caliper and weighed using a household gram scale before being placed in perforated and transparent plastic brood containers measuring 24 X 12 X 16 cm. Moist rubber foam cubes 5 cm thick were used as an incubation medium. The cubes were

Table 2. *Varanus olivaceus* eggs produced at the Avilon Zoo from 2002-2005. Values are expressed as mean (range).

Female No.	Date Laid	Clutch size	Length (mm)	Diameter (mm)	Weight (g)
11	17-Jul-02	10	58.0 (51.0-65.3)	42.0 (40.3-42.8)	46.0 (40.5-52.3)
16	5-Jul-03	6	56.2 (52.0-60.3)	38.9 (30.8-40.2)	39.6 (36.0-43.6)
17	14-Jul-03	4	63.5 (59.3-66.2)	33.6 (32.6-35.2)	46.6 (44.7-48.6)
11	25-Sep-03	13	69.8 (64.5-78.2)	40.5 (38.8-42.2)	56.8 (52.0-62.0)
11	18-Sept-04	8	69.3 (63.3-75.5)	40.2 (38.5-42.3)	53.5 (48.6-60.0)
Overall		8.2 (4-13)	64.2 (51.0-78.2)	39.9 (30.8-42.8)	50.0 (36.0-62.0)

moistened with water to a ratio of 1:2 by weight. The eggs were set firmly on the upper level of the cubes. The upper level was kept dry, the middle level relatively moist, and the lower level perpetually submerged in water. Water at the bottom of the brood containers was maintained at a height of 2.5 cm and refilled when necessary. Additional moisture to increase relative humidity was adjusted by misting the interior walls of the container and the upper level of the incubation media only. The egg containers were subsequently placed in a custom-made acrylic box measuring ca. 60 x 60 x 40 cm (l x w x h) with a perforated lid to function as an incubator. A 50 W incandescent bulb was installed in the upper-most corner of the incubator to provide additional heat. The bulb was switched on in the morning at 0600 h and off in the evening at 1800 h over the course of incubation. The bulb was switched off manually during the hottest part of the day and switched on once again if an increase in temperature was necessary. The egg containers were covered with sheets of newspaper to reduce the intensity of light striking the eggs. Temperature and humidity were monitored and recorded twice daily during the hottest hours of the day and coolest hours of the night using a digital, dual-type thermometer and hygrometer with thermal probes. The thermal probes were placed directly on the surface of the eggs to record temperature and humidity readings. The incubator and egg containers were opened daily, or twice a day if necessary, to facilitate the exchange of oxygen and to eliminate carbon dioxide build up during embryonic development.

Temperature and relative humidity for the 2003 clutch were modified in the latter phase of incubation. Daytime temperature was reduced by 4-5 °C. The relative humidity was reduced by 15-25%, but was increased again to 100% beginning on day 183 in attempt to restore moisture to the remaining two eggs which had become severely indented (see Table 3).

Assisted hatching of neonates

Manual dissection following procedures described by Ross & Merzec (1990) was performed on the two critically indented eggs using a pair of 11.5 cm long stainless steel straight-tipped iris scissors. A small 2.5 cm V-shaped slit was cut along the surface of each egg to check the physical condition of the neonate within. Both neonates were assisted out of the egg by using a stainless steel sexing probe to stimulate motor function by lightly touching the tip of the probe to the body. It took neonate #1 more than 30 min and neonate #2 less than 10 min to emerge. Upon emerging, the two assist-hatched neonates were placed in previously disinfected brood containers with cotton sheeting as a substrate, dampened with 70% ethyl rubbing alcohol to prevent infection of the fresh umbilical scar in neonate #1 and the unabsorbed yolk sac in neonate #2. Surgical procedures were performed immediately to separate the unabsorbed yolk sac from the yolk stalk of the surviving neonate #2 (E.B. Maestro, unpub. dat.) to prevent the yolk sac from being dragged about the tank. The fresh umbilical scars of both neonates were dabbed with Povidone-Iodine. Neonate #1 expired 1 h 45 min after being assisted out of the egg. The yolk sac, measuring 3.3 cm in diameter, was preserved in 70% ethyl rubbing alcohol, and the carcass of the neonate was preserved in a 33% formalin solution (ID: AZCBMu001-03-00162); both were deposited at the Animal Hospital of Avilon Zoo.

Neonate #2 was transferred to the Rearing Department and placed in an acrylic rearing tank measuring 60 x 30 x 30 cm (l x w x h) for post-surgery care and observation. Newspaper was used as substrate. Water was provided in a small, shallow ceramic cup. A Y-shaped tree branch was placed at an angle so that the forked end was 5 cm beneath the wire mesh cover. The rearing tank and all materials within it were

Table 3. Modified incubation parameters for the 2003 clutch of *V. olivaceus* eggs. Abbreviations: DTH = day time high; NTL = night time low; RH = relative humidity.

	Day	Temperature (°C)		RH (%)	No. incubating eggs	No. decomposed eggs	Remarks
		DTH	NTL				
Phase 1	1-50	32.0	30.0	100	3	10	A plastic sheet with minimal perforations covered the top of the brood container; minimal misting
	51-75	31.2	29.0	90	-	-	-
	76-122	31.0	29.0	90	2	1	-
Phase 2	123-154	28.0	25.0	75	-	-	Perforations in the plastic sheet cover were increased; no misting
	155-182	27.5	24.0	75	-	-	-
	183-217	27.0	24.5	100	-	-	Perforations in the plastic sheet cover were decreased; maximum misting

Table 4. Morphometric data of captive-bred *V. olivaceus* hatchlings. Abbreviations: SVL = snout to vent length; TL = tail length; ToL = total length; HW = head width; HL = head length; DistL = distance between front and rear limbs; TBC = tail base circumfrence; WT = mass.

Hatcling No.	SVL (cm)	TL (cm)	ToL (cm)	HW (cm)	HL (cm)	DistL (cm)	TBC (cm)	WT (g)
1	9.95	14.42	12.52	0.18	3	5.2	2.86	12.56
2	11.03	14.51	25.55	0.2	3.22	5.71	3.05	18.28

disinfected using Virkon® S (Pharmacal Research Laboratories, Inc.: Naugatuck, Connecticut, USA). A 25 W incandescent light bulb was placed above the wire mesh cover 10 cm away from the forked end of the tree branch to provide a basking spot for thermoregulation. Morphometric data (Table 4) were taken on day 3 for neonate #2 and upon the death of neonate #1.

Food and feeding of the neonate

Mango puree mixed with NutriBird p15® pellets (Versele-Laga: Deinze, Belgium) and softened in lukewarm water, diced ripe bananas, and week-old crickets (*Acheta domestica*) were offered on day one. Although fish is not a known food item of *V. olivaceus*, small guppies (*Poecilla reticulata*) placed in a dish of swallow water were also offered on the same day as an experiment.

A decision was made to tube-feed the neonate on day two. Neonate #2 was tube-fed using a 3 ml syringe with a small-gauged (ca. 3 mm) feeding tube. A dinner fork was used to pry open the mouth of the neonate as the lubricated catheter was inserted between the tines of the dinner fork and carefully into the stomach through the esophagus. Chicken egg yolk with a pinch of Nutri-Cal® (Vetoquinol USA, Inc: Forth Worth, Texas, USA) amino acid paste at 1 ml was given on a once-every-two-days basis for the first week (days 2-8) and 2 ml for the second week (days 9-15). Starting day 17, live food consisting of freshly-molted mealworms (*Tenebrio molitor*), superworms (*Zophobas morio*), *A. domestica* (dabbed with Reptocal® [Tetra-Terrafauna: Morris

Plains, New Jersey, USA] prior to feeding), tiny chunks of fresh, lean chicken and beef were offered in feed cups.

Neonate #2 received natural sunlight twice per week, between 0830 and 0930 h. Temperature of the neonate's skin was recorded using a hand-held infrared thermometer (La Crosse Technology, China).

Results and Discussion

Feeding behavior in captive adults

Owing to the complexity of its frugivorous feeding habit, *V. olivaceus* is considered one of the more difficult species to maintain and breed in captivity when compared to its more adaptable, carnivorous congenerics such as *V. komodoensis* (*e.g.*, Visser *et al*., 2009); *V. salvator macromaculatus* (*e.g.*, Dwyer & Perez, 2007; Yuyek, unpub. dat.); *V. cumingi* (*e.g.*, Wicker *et al*., 1999); and *V. exanthematicus* (*e.g.*, Bennett & Thakoordyal, 2003).

During initial feeding trials, all captive *V. olivaceus* refused commercially available fruits such as bananas, watermelon, papaya, and cantaloupe. Captives at the Dallas Zoo that had been subsisting on rodents also rejected commercial fruits, but later on accepted grapes (Card, 1995). Grapes were not offered to captives at the Avilon Zoo due to their high cost, seasonality, and limited availability in local markets. The Santol (*Sandoricum koetjape*) of the family Meliaceae was reported to have been eaten by wild *V. olivcaeus* (Auffenberg, 1988), but *S. koetjape* on Polillo Island, according to Bennett (pers. comm.), grows to the size of a baseball and if swallowed whole might result in blockage of the esophagus of a *V. olivaceus*. When offered as whole or sliced, the smaller variety of *S. koetjape* growing in Avilon Zoo was rejected by captives (pers. obs.).

Since fresh chicken heads were acquired in bulk quantities to feed carnivorous animals at the zoo and were freely accepted by captive *V. olivaceus,* they were selected as their staple diet; chicken, however, was absent from the guts of both captive and wild *V. olivaceus* studied by Auffenberg (1988). Not all captives voluntarily accepted rodents; some individuals required tease-feeding. Eventually, all captives subsisted on a diet of chicken heads and rodents without any trace of fruits whatsoever.

Protein derived from animal sources is essential for growth and breeding activities in varanids (Sprackland, 1992). Chicken heads, which are a good source of protein, fats and calcium, constituted a large portion of the captives' dietary intake. However, there have been negative effects from feeding a purely animal-based diet to *V. olivaceus*. Individuals subsisting on this diet for long periods of time tended to develop visceral gout and gastrointestinal infections as a result. Post-mortem examinations performed on seven captive adults indicated that necrotic tissues found in the gastrointestinal lining were most likely associated with long-term intake of protein-rich foods, which are very low or totally deficient in roughage (P. Hidalgo, unpub. dat.).

Although molluscivory is partial to the diet of *V. olivaceus* (Auffenberg, 1988; Bennett & Hampson, 2003; Bennett, 2005; King, 2008) and of other varanid species (*e.g.*, Bennett, 2000, 2002, 2003; Arbuckle, 2009), apple snails, *Pomocea canaliculata*, inhabiting rice paddies near the Avilon Zoo (up to 150 individuals per m2 [Cowie, 2006]) were never fed to captive *V. olivaceus* for fear that that some might have been contaminated with molluscicides (Hairston, 1965) that were periodically applied to the those areas (pers. obs.).

Apart from land snails, crustaceans are also preyed on by *V. olivaceus* in the wild (Auffenberg, 1988; Bennett & Hampson, 2003). Other varanids are also known to eat crabs (Bennett, 2002). Crabs were never offered to captive adult *V. olivaceus*, but *talangka,* or small river crabs (*Varuna litterata*) were offered to the captive-bred neonate. Blue marine crabs (*Portunus pelagicus*), known locally as *alimasag*, were reported to have been accepted by a captive adult in a private collection in which only the legs and pincers were consumed (N.H. Margarico, pers. comm.).

In captivity, *V. olivaceus* were observed to be fastidious feeders. Since olfaction predominates other senses in this species, thawed chicken heads and pre-stunned rodents were first investigated and tongue-flicked repeatedly for up to 10 min, and sometimes longer, before they were consumed. Uneaten chicken heads left inside the enclosure for long periods of time were rejected by captives, particularly those on the verge of decomposition and infested with flies.

Clusters of *Pandanus* (most likely the fragrant screw pine, *P. tectorius*) and black fiber palm (*Pinanga insignis*) have been planted in the zoo but have yet to mature and bear fruits. Fishtail palms (*Caryota rhumphiana*) and MacArthur palms (*Ptychospermum macarthurii*) at the zoo have recently begun bearing fruits, but these have yet to be test-fed to captives.

Reproductive behavior

Sex determination in varanids can be problematic (Horn & Visser, 1997). Sexing by way of hemipeneal probing is unreliable (Andrews & Gaulke, 1990; Card, 1995; Gaulke *et al.*, 2005). Radiography, one of the reliable methods for accurately sexing *V. olivaceus,* was described by Card (1995). In addition, Auliya & Erdelen (1999) explained that radiographing the hemibacula is not a reliable method for all varanid species. Due to the lack of radio-opaque tissues, *V. salvator* cannot be reliably sexed using radiography (Card & Kluge, 1995). Conclusive sex determination is best achieved by using endoscopy (Schildger & Wicker, 1992; Schildger *et al.*, 1993; D. Bennett, pers. comm.). In contrast to these above-mentioned methods, all *V. olivaceus* at the Avilon Zoo had been sexed using traditional methods (e.g., hemipeneal probing and comparison of morphological differences) since endoscopy and radiography were inaccessible at that time, and 80% of the determined genders were found to be correct.

Reproductive behaviors were observed from 1995-2004. Pre-copulatory interactions began in May and continued throughout the rainy months of June, July, and August. Similar interactions were also observed during these months in other varanids at the zoo, including *V. marmoratus* (Yuyek, unpub. dat.; N.H. Margarico, per. comm.), *V. cumingi* (Yuyek, 2004c), *V. exanthematicus* (Yuyek, 2005a), *V. salvadorii* and *V. bengalensis nebulosus* (Yuyek, unpub. dat.).

Ritualistic bipedal combat between male *V. olivaceus* reported by Auffenberg (1988) was not observed in the 2002 breeding group when two males were housed together with two females. Observations of most breeding attempts indicated that breeding males and females regularly stayed in close contact to one another for several days prior to the onset of actual courtship. Courtship was observed to have always been initiated by the male and would continue sporadically for a period of 2-3 weeks. During the breeding season of 1995, it was noted that courting male #1 exhibited much greater interest in the larger female #3 than the smaller female #2, persistently following female #3 around the enclosure, flicking its tongue along her tail base, and staying close together. Auffenberg (1988) described cohabitation in wild *V. olivaceus*; however, it is unknown whether male #1 and female #3 had been cohabiting in the wild prior to being captured. It was also suspected that female #2 was probably non-receptive at the time of this courtship. Female #2 avoided these two sexually active individuals by retreating to, and curling up in the corner of the enclosure during the peak of courtship activities, and never ascended the tree branches. This submissive behavior in smaller, non-receptive females was also observed in captive *V. cumingi* (1:3 male to female ratio) during the breeding season in 2007. The *V. cumingi* male's sexual interest was directed at the larger female of the group at all times. Smaller females tended to move away when approached by the larger female, often retreating to a nearby shelter and remaining there for days without showing interest in food (pers. obs.). Copulation in captive *V. olivaceus* was opportunistically observed in 1995, 2003, and 2004, but was often interrupted by human activity around the enclosure.

Dominance and aggression similar to those seen in male varanids were not observed in any captive female *V. olivaceus*, but were observed in other varanid species at Avilon Zoo, and size appears to be a major factor. For example, conspecific aggression in *V. cumingi* occurred after the introduction of a non-resident female to the enclosure of a resident male during the breeding season of 2003 (Yuyek, 2004c). Aggression was initiated by the female at the very instance when the male attempted to mount the female. As a result, the left hind foot of the female was severely mutilated from bites inflicted by the male and had to be amputated. Eleven days after amputation, the female died from a systemic infection, and egg follicles were retrieved from the oviducts during necropsy (E.B. Maestro, unpub. dat.). Engle (unpub. m. s.) observed aggressive behavior in a gravid female *V. keithornei* towards males and other females, and female dominance behavior has also been observed in captive *V. marmoratus* and *V. bengalensis nebulosus* (pers. obs.).

In the 1994 *V. olivaceus* breeding stock, pre-copulatory interactions took place unexpectedly on 29 July and continued sporadically until 17 August. Copulation was observed in the morning of 18 August 1995 between male #1 and female #3 (Table 5). Due to the shy nature of *V. olivaceus* (Bennett, 2005), observations were made at a distance of ca. 3 m from the enclosure whilst the pair was engaged in copulation. Copulation was not repeated with the same female or attempted with the smaller female afterwards.

Despite a noticeable enlargement of the female's abdomen in the following months, oviposition did not occur. *Varanus olivaceus*, both in the wild and in captivity, have never been reported to consume their own eggs, the eggs of conspecifics, or those of other animals. Although ovophagy appears to be a common dietary character in other monitor species (*e.g.*, Arbuckle, 2009; Cota, 2011), it is unlikely to occur in *V. olivaceus*. Therefore, it is doubtful that eggs were laid and then eaten. No reports on the resorption of oviductal eggs in gravid *V. olivaceus* exist at the time of this writing, although it has been reported in other species of reptiles (Blackburn, 1998).

Table 5. Copulatory data for *V. olivaceus* at Avilon Zoo.

Year	Male No.	Female No.	Date	Time	Duration of Copulation	Temperature (°C)	RH (%)	Weather Condition
1995	1	3	18-Aug	1045 h	8 min 15 s	29.6	78	Sunny
2003	9	11	8-Aug	0610 h	9 min 20 s	26.5	72	Overcast
			10-Aug	0645 h	7 min 06 s	27.6	74	Raining
			11-Aug	0710 h	11 min 25 s	30.2	82	Sunny
			14-Aug	0620 h	4 min 03 s	26.2	77	Raining
			21-Aug	0605 h	6 min 42 s	27.5	70	Overcast
2004	18	11	2-Aug	1415 h	10 min 28 s	29.5	72	Sunny
			5-Aug	0810 h	4 min 55 s	26.5	77	Sunny

Breeding attempts were temporarily suspended from 1998 until 2001 due to high mortality rates when three adults and two sub-adults from the 1995 brood stock died of chronic respiratory tract infections between 1997 and 2000. Clinical signs resembled that of inclusion body disease (IBD), a commonly encountered viral infection in the family Boidae (Stahl, 1996). Conclusive diagnosis could not be determined due to the absence of a veterinary staff and laboratory at that time.

Breeding attempts were reinstated in early 2002. Although copulation was not observed in those pairs from the 1998 breeding stock (male #7 and female #12; male #9 and females #11), 10 eggs were found scattered on the substrate by female #11 (R. Madriaga, pers. obs.) and 6 were submerged in the pool. These eggs began to decompose after 15 days of incubation.

In early July 2003, two separate cases of oviposition were observed in two young adult females (#16 and #17) from Catanduanes Island that were housed with male #15. A number of misshapen eggs were laid in both clutches. Three weeks prior to oviposition, sporadic courtship interactions between individuals were observed. On 5 July 2003, female #16 deposited a clutch of six eggs, with an additional five eggs, all of which were misshapen, laid three days later. A clutch of seven eggs was laid by female #17 on 14 July, of which four appeared viable. Eggs from both clutches (A and B) were simultaneously incubated in the same manner as that used for the 2002 clutch. These eggs became flaccid and began to sweat on the third day of incubation and eventually began to deteriorate, becoming infested with maggots by day 10.

The zoo's third breeding attempt between male #9 and female #11 began in late June 2003. These individuals were selected on the basis of pre-copulatory behaviors observed after being introduced to one another. Female #11 was removed from Cage A of the outdoor enclosure and transferred to the newly constructed outdoor exhibit enclosure. Four weeks prior to the onset of monsoon rains, male #9 was introduced to the female. Vigorous courtship activities began on 30 July and continued infrequently for another two weeks. Copulation was observed on 8 August at 0610 h and lasted 9 min 20 s. Temperature and humidity inside the enclosure at this time was 26.5 °C and 72%, respectively. Four subsequent copulations were observed, ending on 21 August (Table 5).

Another breeding attempt using male #18 and female #11 was carried out on 2 August 2004. After copulations were observed and the female had lost sexual interest, the male was removed from the enclosure. Although frequently investigated, a hollow coconut palm trunk nest box was ignored by the gravid female, and eight eggs were deposited atop the substrate. The eggs were incubated in the same manner used for the clutch in 2003, but decomposed shortly thereafter (Fig. 3).

Copulatory positions in *Varanus* are generally similar to those exhibited by other lizards including the families Iguanidae, Agamidae, Gekkonidae, and Scincidae. Captive male *V. olivaceus* usually mounted submissive females from behind, following a series of jerking head movements, tongue flicking, and scratching of the female's body along the head, neck and back. Males differed in their usage of the hemipenes during copulation; male #1 in 1995 and male #7 in 2003 used the right hemipenis, whereas male #18 in 2004 used the left. Copulation always occurred on land and never in water as observed in *V. cumingi* (Wicker *et al*., 1999; Yuyek, 2007, pers. obs.) and *V. salvator macromaculatus* (Cota, 2011).

Table 6. Comparison of egg production in captive *Varanus* at Avilon Zoo 1995-2008.

Species	No. females	Year	No. eggs laid	No. incu-bated	No. hatched	No. of surviving hatchlings	Comments
marmoratus	1	2002	8	8	5	5	Captive-hatched from wild-collected eggs
cumingi	1	2002	8	5	-	-	Three full term embryos died in egg; in preservative
exanthematicus	1	2003	12	6	5	3	Captive-bred and hatched
olivaceus	6	1995	10	41	2	1	One hatchling died shortly after being assisted hatched; in preservative
		2003	23				
		2004	8				
salvadorii	1	2007	4	4	-	-	Mated in captivity

Unlike other varanid species that deposit their eggs in burrows dug in the ground (*e.g.*, Wicker *et al*., 1999; Dwyer & Perez, 2007; Coiro, 2007; Visser, *et al*., 2009) or in termite mounds (*e.g*., Bennett & Thakoordyal, 2003), hollow tree trunks are probably utilized as nesting sites by *V. olivaceus* in the wild. Despite having various nest sites provided, egg deposition atop the substrate has also been observed in *V. keithornei* (Engle, unpub. m.s.), and is identical to the egg laying behavior of captive *V. olivaceus* at Avilon Zoo. This abnormal behavior is likely related to insufficient nest sites or nesting options.

Clutch sizes, egg morphometrics, and incubation

Communal housing of 1.2 (males.females) *V. olivaceus* in 1995, 2.2 in 2002, 1.2 in 2003, and 1.1 in 2004 resulted in zero egg production in 1995 and non-viable eggs in 2002, 2003 and 2004. A total of five clutches (n=64) were produced by the three females between 2002 and 2005 (Table 5). Single clutches of 16, 16, and 14 eggs were laid by the same female (#11) on 17 July 2002, 25 September 2003, and 18 September 2004, respectively. In addition, single clutches of eleven and seven eggs were laid by two Catanduanes females (#16 and #17) on 5 and 14 July 2003, respectively. Of the 64 eggs produced, 23 were either misshapen or found submerged in the pond. The average number of viable eggs (n=41) per clutch was 8 (range 4-13), with an average of 20 eggs received per year. Mean and overall range in egg length, diameter, and weight was 64.2 mm (51.0-78.2), 39.9 mm (30.8-42.8), and 50.0 g (36.0-62.0), respectively. Table 6 compares clutches produced by captive varanids at the Avilon Zoo.

Reptilian clutch size is often associated with the size and age of a female (Auffenberg, 1988; Sumiller, 1998). Card (1994) reported double-clutching in *V. olivaceus* at the Dallas Zoo. Multi-clutching (*e.g*., Retes & Bennett, 2001; Bennett & Thakoordyal, 2003; Mendyk, in press), parthenogensis (Lenk *et al*., 2005; Hennessy, 2010), and twinning (*e.g*., Mendyk, 2007) were not observed in *V. olivaceus* or any other varanid species at the zoo.

Using foam rubber cubes to incubate reptilian eggs was described by Schmidt (1995). Eggs of various species of snakes and lizards have been successfully hatched at the Avilon Zoo using this method (Yuyek, 2004b, 2005a, 2006). Reptile eggs incubated at the zoo using a mixture of fluvial sand, coco peat, potting

Figure 3. Deteriorating eggs of *V. olivaceus* laid in 2005. Photograph courtesy of **Neil Hendrix Margarico**.

soil, and humus resulted in high egg mortality, except for those of *Python reticulatus* which were maternally brooded on soil substrate (Yuyek, 2004d).

Eggs of *V. olivaceus* laid between 2002 and 2004 were artificially incubated in a similar fashion to the methods described by Andrews & Gaulke (1990) for *V. salvator*, except for the type of incubation medium used, which followed Schmidt (1995). Most eggs, however, began to deteriorate within the first 10 days of incubation, probably due to infertility or since all eggs were not nested properly. Several factors, such as inadequate nesting sites or eggs that were held too long by the female might have contributed to poor egg success during incubation. The lack of egg viability for the two clutches laid by Catanduanes females (#16 and #17) was most likely associated with poor nesting conditions since nesting areas were not provided and the eggs were laid on the floor of the steel holding cage.

Auffenberg (1988) reported that spermatogenesis in male *V. olivaceus* is largely influenced by seasonality, and takes place from July through September, with May to July being peak months. Courtship and copulatory behaviors in captive *V. olivaceus* at the Avilon Zoo from 2002-2004 coincided with these months when spermatogenesis is greatest.

Assisted hatching

Many eggs from the September 2003 clutch (n=13) began to deteriorate during the early stages of incubation. On day six, egg #s 2, 3, 9, and 11 appeared discolored and bloated, and by day 14, all but egg #s 4, 7, and 8 had deteriorated. Egg #4 deteriorated after 102 days of incubation. No near-term embryos were found in any of the deteriorated eggs.

On Day 182, depressions started to develop in the remaining two eggs (#7& 8), with the denting in egg #7 more severe than that of egg #8. Humidity inside the egg container was increased to 100% under the assumption that doing so would restore moisture to the eggs; however, despite this increase, no significant changes in the egg were observed. In contrast to the 214 day incubation period recorded at the Dallas Zoo (Card, 1995), *V. olivaceus* incubation at the Avilon Zoo took 209 and 217 days, under the modified incubation setting.

On Day 209, a decision was made to manually open the first egg to prevent the neonate from dying inside. Upon dissection, the late-term neonate was found lodged between its large, unabsorbed yolk sac and the indented portion of the egg. After it was freed from the egg, neonate #1 showed poor prognosis in neuromuscular and respiratory functions and expired 3 h 45 min later, despite efforts to prolong its life.

Neonate #2 was also assisted with hatching in the same manner as neonate #1. Upon its emergence, vital signs appeared normal, except for the attached yolk sac that required immediate ligation (Figs. 4 & 5). Engle (unpub. ms.) reported unabsorbed yolk syndrome in a captive-bred *V. keithornei*, which was also surgically ligated. The respiratory rate of neonate #2 was recorded at 10 breaths per min (E.B. Maestro, unpubl. dat.).

The low hatch rate of *V. olivaceus* eggs may suggest flaws in captive diets for adults as well as incubation techniques. Husbandry and reproductive management practices were based largely on trial and error due a lack of comprehensive literature on the keeping and breeding of frugivorous monitor lizards.

Neonatal coloration and pattern

The coloration and pattern of neonatal *V. olivaceus* are different from that of adults. The upper half of the

Figs. 4 & 5. The assist-hatched captive-bred *V. olivaceus* with attached yolk sac minutes after emergence.

dorsum is yellowish-brown in ground color and speckled with tiny black spots, with five solid black transverse bands extending from the nuchal to axilla regions (Figs. 6 & 7). The lower half of the dorsum is black in ground color with numerous irregular bluish-white spots forming seven light, irregularly-spaced transverse bands that terminate at the dorsolateral region. The upper and lower labials are splashed with bright orange coloration. The cranium is bright olive green with tiny black spots, and a distinct black temporal stripe extends from the postocular to the anterior part of the ear. The forelimbs and hind limbs are bluish-black with numerous tiny white spots, and the base color of the tail is solid black with 8-15 distinct white bands. The underside of the head and throat and the venter are tannish grey with thin transverse grey bands (Fig. 8).

Rearing of the captive-bred neonate

Selecting specific types and quantities of food items for the neonatal *V. olivaceus* was initially problematic in that there appears to be a slight difference in the dietary preferences between this species and other neonatal varanids. It is likely that neonatal varanids have similar dietary preferences for insects and other invertebrates, then transition to different food items when a certain size or level of maturity is reached. *Acheta domestica* let loose on the tank floor were ignored by the neonate, but were later accepted when offered in feed cups. Hermann (1999) reported similar observations, where some captive-bred neonatal *V. salvator* would only take food from feed cups.

The neonate did not show any interest in solid food until day 17. The first food items taken from the feed cups were three recently molted *Z. morio*, followed by five *A. domestica*, and finally, one small chunk of beef and two small chunks of chicken after they were tongue-flicked several times. Olfaction appeared to be more important to *V. olivaceus* for detecting prey than eyesight, which agrees with observations made on juvenile *V. exanthematicus* (Bennett, 2000).

The maximum skin temperature recorded for the neonatal *V. olivaceus* during thermoregulation at 0945 h was 41.3 °C (E.B. Maestro, unpub. dat.). When this maximum body temperature was achieved, the neonate moved away from the basking spot; even if it was repeatedly returned to the same place by the keeper. Core body temperatures were not recorded due to the fragile condition of the neonate. The lighter head coloration of the individual and its wide dorsal bands speckled with irregular, tiny white spots are presumably capable of reflecting solar radiation, enabling a higher degree of tolerance to solar radiation exposure than other species with darker overall body coloration. Captive *V. olivaceus* adults at the Avilon Zoo weighing 4.2-8.6 kg have been recorded thermoregulating at a range of 39.5-40.2 °C for durations of up to four hours without showing signs of heat distress (pers. obs.). Auffenberg (1988) reported

Figs. 6 & 7. Dorsal coloration and pattern of captive-bred neonatal *V. olivaceus.*

Fig. 8. Fresh umbilicus and ventral coloration and pattern of captive-bred neonatal *V. olivaceus.*

heat distress in *V. olivaceus* (age not specified) at a range of 41.6-42.4 °C.

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Varanus salvator ssp. Langkawi, Malaysia. Photograph by **Yves Faes-Dupont**.

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Varanus mertensi. Litchfield National Park, NT. Photograph by **Francesca Fuga**.

CURRENT RESEARCH

Scanning Electron Microscopy (SEM) of Monitor Lizards' Scale Ultrastructure: Systematic Implications

YANNICK BUCKLITSCH, WOLFGANG BÖHME & ANDRÉ KOCH

Zoologisches Forschungsmuseum Alexander Koenig, Section of Herpetology
Adenauerallee 160, 53113 Bonn, Germany
Corresponding author: andrepascalkoch@web.de

Because monitor lizards, in contrast to most other squamate lizards, lack differentiated head and body scales (Fuchs & Fuchs, 2002), except for the enlarged supraoculars and enlarged to spinose neck scales in some species, the use of scalation features for systematic questions is generally confined to quantitative analyses, which help to distinguish between species with larger, and thus fewer scales, or those with smaller, and consequently more body scales (*e.g.*, Mertens, 1942; Brandenburg, 1983; Böhme *et al*., 1994; Koch *et al*., 2010b).

While the microstructure of body scales has been used in various other squamate reptiles to differentiate between distinct species and even higher taxonomic categories (*e.g*. Stewart *et al*., 1973; Arnold, 2002), this methodological approach is now applied for the first time to lizards of the family Varanidae.

Across all nine recognized subgenera of the genus *Varanus* scale shape and structure were analyzed using scanning electron microscopy (SEM). In a preliminary approach, we investigated the dorsal scales of 37 species (*i.e*. >50% of the species currently recognized) in order to answer the question if qualitative scalation features are useful for systematic issues. Our results show that a microornamentation (ultradermatoglyphics) as seen in various squamate groups is also partly present in monitor lizards. However, only in a few, albeit unrelated, monitor species examined do the dorsal scales exhibit a specific honeycomb microstructure (Fig. 1). The ecological meaning of this microstructure, if any, remains unknown. Nevertheless, scale shape as well as the extent and size of granula rows around the main scales allow differentiation between single species, even among close relatives, such as the members of the *V. indicus* species group (Ziegler *et al*., 2007). Special attention was paid to *V. spinulosus* Mertens, 1941, a rare endemic

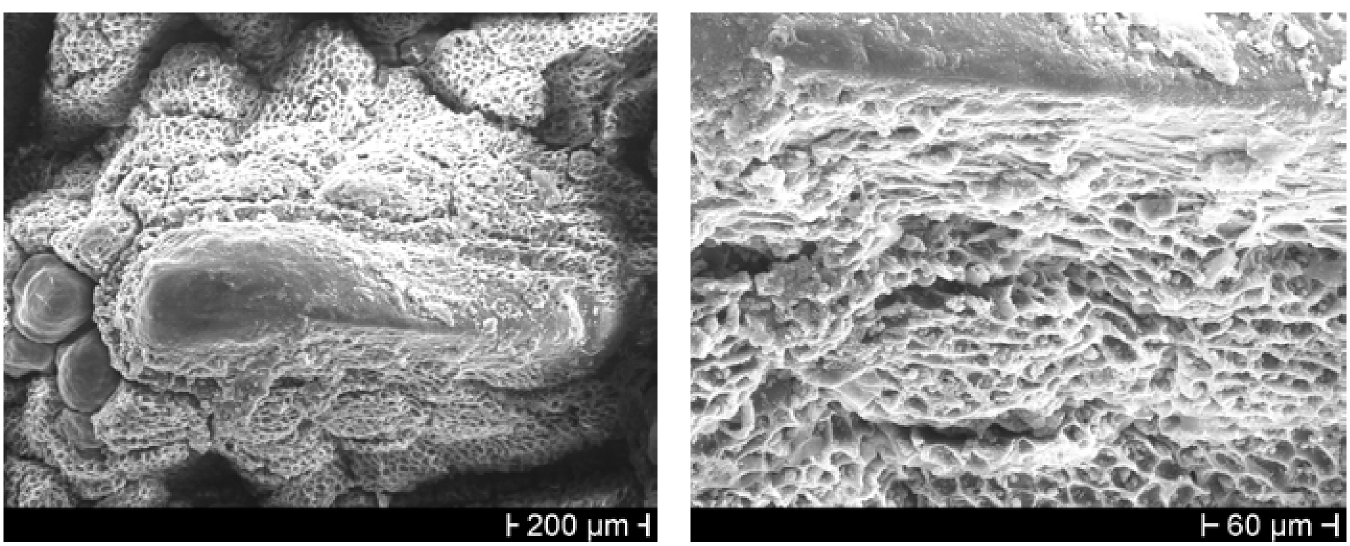

Fig. 1. SEM photos of dorsal scales from the midbody region of *Varanus salvadorii* (ZFMK 72258) from New Guinea (125x, 400x). Note the honeycomb-like structure in this specimen.

from the Solomon Islands that exhibits a unique skin texture. Due to its first description as a subspecies of *V. indicus* by Mertens (1941), it was formerly allocated to the subgenus *Euprepiosaurus* (Ziegler & Böhme, 1997), which comprises the *V. indicus* and *V. prasinus* species groups. However, recent investigations of the hemipenial morphology of *V. spinulosus* suggested a closer phenetic relationship to *V. salvadorii* (subgenus *Papusaurus*) from New Guinea (Böhme & Ziegler, 2007). Currently, its systematic and phylogenetic position within varanids is uncertain (Koch *et al*., 2010a).

Investigations of the dorsal body scales showed big differences in scale shape and scale size as well as in the occurrence and extent of a honeycomb-like ultrastructure among the *Varanus* species examined (see Figs. 1-4). *Varanus spinulosus* has strongly conical scales which are rather irregular but mostly oval in shape. The granula surrounding the dorsal scales are also conical or domed and of irregular size. In addition, the scales are strongly keeled (Fig. 2). This scalation feature is only found in *V. spinulosus*. In contrast, *V. salvadorii* has drop-shaped scales and a rough scale surface composed of a honeycomb-like structure at the scale margins and on the surrounding granula. Furthermore, some slightly enlarged pre-scale granula are present at the posterior scale margin (Fig. 1). Within the heterogeneous subgenus *Euprepiosaurus*, *V.* cf. *finschi* of the *V. indicus* group shows an oval scale shape with enlarged granula flanking the dorsal scales (Fig. 3), while the dorsal scales of *V. prasinus* and its allies are

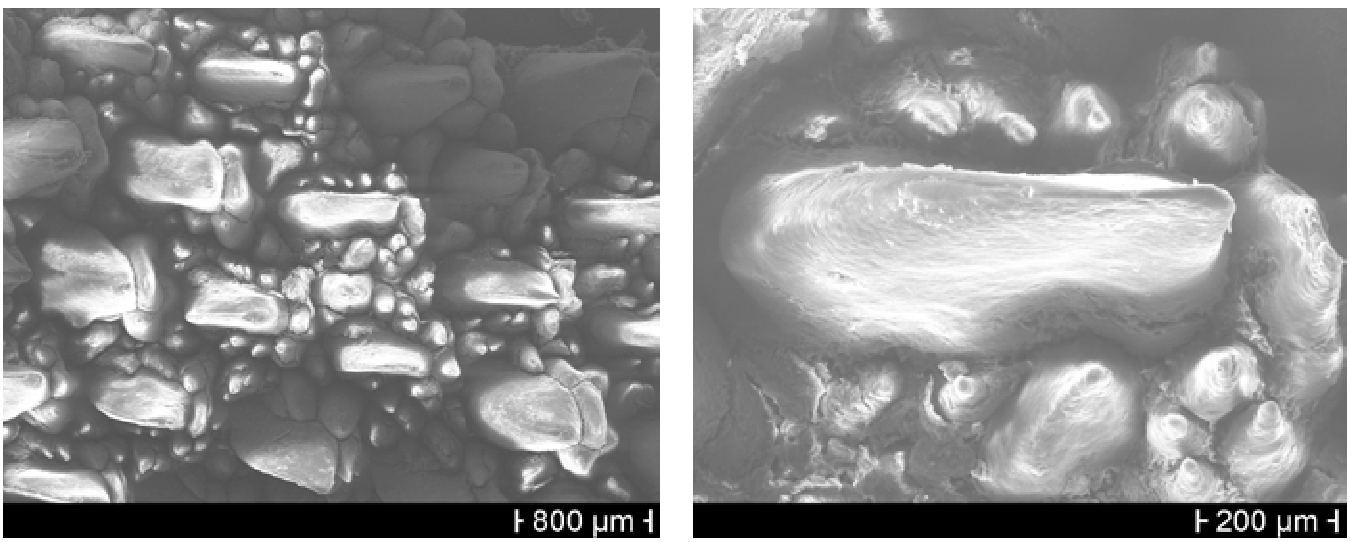

Fig. 2. SEM photos of dorsal scales from the midbody region of *V. spinulosus* (ZFMK 90607) from the Solomon Islands (30x, 125x). The strongly conical scales are unique among monitor lizards.

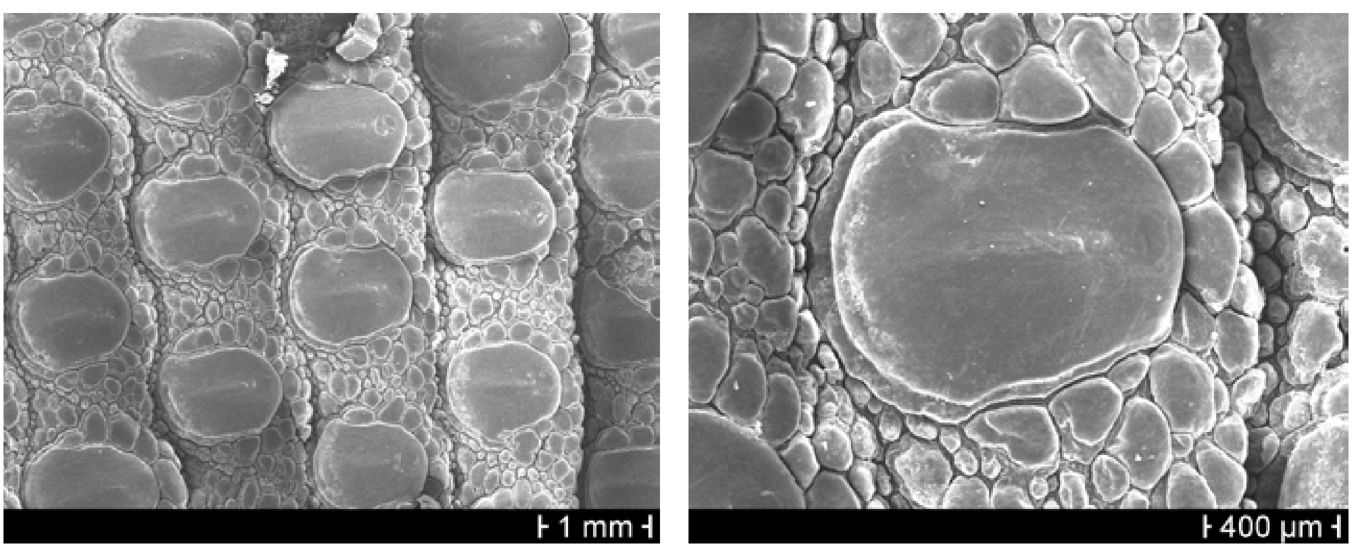

Fig. 3. SEM photos of dorsal scales from the midbody region of *V.* cf. *finschi* (ZFMK 84982) from the Kai Islands, Indonesia (20x, 60x).

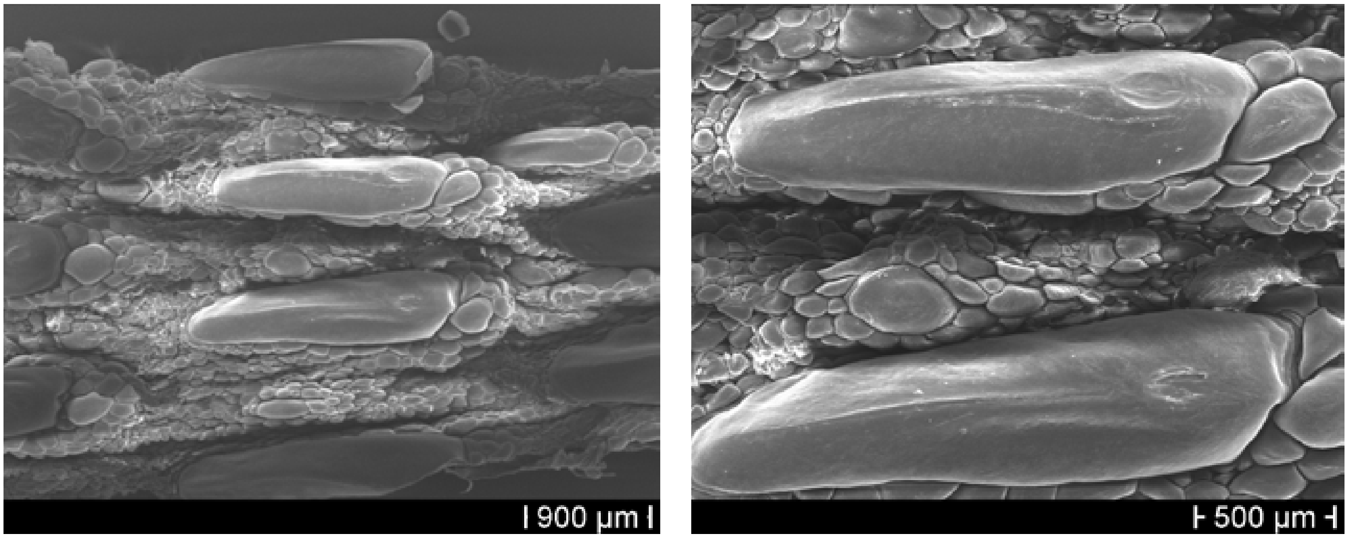

Fig. 4. SEM photos of dorsal scales from the midbody region of *V. prasinus* (ZFMK uncataloged) from New Guinea (25x, 50x). Tree monitors exhibit characteristically elongated dorsal scales.

elongated and exhibit enlarged pre-scale granula (Fig. 4).

Our preliminary investigations of the dorsal body scales showed large differences in scale shape and size as well as in occurrence and extent of a honeycomb-like ultrastructure among the various *Varanus* species examined. The morphological investigations revealed that dorsal scale shape and the extent of granula rows are useful taxonomic characters for the identification and demarcation of different monitor lizard species and their affiliation to distinct subgenera of *Varanus*. In addition, we are able to conclude that an ultrastructure is rarely found in monitor lizards and seems to have no evolutionary implications because it occurs in species with different ecological adaptations such as arboreal rainforest species (i.e. *V. salvadorii*) and terrestrial desert dwellers (i.e. *V. griseus*). In addition, we are able to postulate that *V. spinulosus* represents a new monotypic subgenus. Our preliminary results support the assumption that the *V. prasinus* group may represent a new subgenus distinct from *Euprepiosaurus* s. str. based on the morphological differences in scale shape and structure.

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Zoos and Private Keepers Sought for Participation in Varanid Behavioral Research

Mendyk & Horn (2011) described a fascinating foraging behavior in the black tree monitor *Varanus beccarii* in which lizards used coordinated forelimb movements to reach into narrow tree holes and extract hidden prey (Fig. 1). Since the publication of this report, forelimb-assisted extractive foraging has been observed and confirmed in several additional varanid species by zoos and private herpetoculturists. The discovery of this behavior in species other than *V. beccarii* raises the question of just how extensive is this behavior in the genus *Varanus*?

In an effort to better understand the mechanics of this behavior and its usage by other varanid species, behavioral data is currently being compiled on species presently maintained in captivity. To maximize the number of species analyzed in this study, correspondence and feedback is sought from both private varanid keepers and zoological institutions that are able and willing to test for the usage of this foraging technique in captives. Any assistance or participation will be rightfully acknowledged.

Those interested in participating in this behavioral study should contact the primary investigator for specific details and additional information.

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ROBERT W. MENDYK
Center for Science Teaching and Learning
1 Tanglewood Road
Rockville Centre, NY 11570
E-mail: odatriad@yahoo.com

Fig. 1. Forelimb-assisted extractive foraging in *Varanus beccarii*.

Varanus cumingi. Captive, London Zoo. Photograph by **Sophie L. Miller.**