BIAWAK

Quarterly Journal of Varanid Biology and Husbandry

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On the Cover: *Varanus keithhornei*

The *Varanus keithhornei* depicted on the cover of this issue was photographed by **Mark Sanders** in Iron Range National Park, Queensland in November 2001. The specimen was first seen walking along the ground in a forested area around 1100 h near the smuggler's tree, a large landmark *Ficus* tree in Iron Range NP, before it ascended a small tree, where it was photographed before climbing up into the canopy.

Two additional *V. keithhornei* were observed on the same trip in 2001, both of which were initially seen on the ground before fleeing to the nearest tree. A follow-up trip to Iron Range NP in October 2003 failed to locate any *V. keithhorni*.

About the photographer: **Mark Sanders** (colonel_007@hotmail.com) has been a keen naturalist since a child and currently works as an environmental consultant specializing in terrestrial vertebrates. While based in Brisbane, he has widely travelled across Australia for personal interest and work purposes, resulting in direct observations of almost 1300 Australian vertebrates. His digital photography can be viewed at http://www.flickr.com/photos/31350467@N04/

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Quarterly 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*, a quarterly journal of varanid biology and husbandry, and is available online through the IVIG website.

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Varanus mertensi. Purnululu, WA. Photograph by **Mal Chandler**

New Additions to the Editorial Board

The IVIG welcomes George Sunter of the Zoological Society of London's London Zoo (UK) and Brandon L. Greaves of Omaha's Henry Doorly Zoo (USA) to the editorial board of *Biawak* as zoo liaisons.

Logo Needed for the IVIG

The IVIG is currently seeking an official insignia to represent the organization online, at events, in publications and on organizational documents. Entries should be submitted electronically in jpeg format and be no smaller than 2400 x 2400 pixels. The only rigid requirement for the design is that it must include the IVIG's unabbreviated name, "International Varanid Interest Group". The winning design shall be announced and unveiled in a future issue of *Biawak*. Design entries should be submitted to: submissions@varanidae.org
The deadline for submissions has been extended to 15 August 2009.

Seeking Zoo Liaisons

The IVIG is currently seeking motivated individuals from African, Asian and Australian zoological institutions to join the editorial board as zoo liaisons. Primary duties will include networking with zoological institutions to report quarterly announcements of recent captive breedings as well as promoting *Biawak* to herpetology departments in zoos and aquariums in your respective region. For additional details, please contact the IVIG at info@varanidae.org.

Varanus salvadorii. Captive. Tropicario, Helsinki, Finland.
Photograph by **Harri Väyrynen**. http://www.flickr.com/photos/harrivayrynen/

Report from the First Annual Meeting of the "AG Warane"

The first annual meeting of the re-established "AG Warane" of the DGHT took place on 18 April 2009 in Hanau near Frankfurt. About thirty German monitor enthusiasts attended the meeting.

The program was opened by Klaus Wesiak (Frankfurt) with a talk about the successful keeping and breeding of *Varanus auffenbergi*. Rudolf Wickert from the Frankfurt Zoo talked about his experiences in monitor keeping at the 'Exotarium' during the last twenty-five years. Remarkably, the Frankfurt Zoo has kept and bred the Mindanao water monitor (*V. cumingi*) from the Philippines for more than two decades.

Later, Ulf Riedel and Klaus Wesiak (both from Frankfurt) reported on a case of breeding in *V. albigularis* with complications, which required surgical interventions. In many slides, it was demonstrated that egg-binding represents a well-treatable problem, if it is recognized at an early stage.

With humour, and technically-versed, Dietmar Kiehlmann (Overath) talked about his experiences of forty years of monitor keeping. Once, for instance, he met professor Robert Mertens, Germany's renowned herpetologist and author of several monitor species descriptions.

André Koch (ZFMK, Bonn) closed the meeting with a scientific talk about systematics and endemism of Indo-Australian monitor lizards.

Jacksonville Zoo Welcomes Komodo Dragons

The Jacksonville Zoo, in Jacksonville, Florida, USA has recently celebrated the grand opening of its new Asian Bamboo Garden exhibit. Featured within this exhibit, in addition to a walk-through garden featuring over 30 types of bamboo, are two adult male *Varanus komodoensis*. According to zoo officials, the *V. komodoensis* are to be part of a captive breeding program once an adult female is acquired.

Source: News4jax.com- 6 March 2009

Man Dies from Komodo Attack

An Indonesian fisherman was attacked and killed by Komodo dragons (*Varanus komodoensis*) while in search of fruit in an area forbidden for people to enter at Loh Sriaya, Komodo National Park, Indonesia. Thirty-two year old Muhamad Anwar bled to death on his way to a hospital on nearby Flores Island after sustaining bites from two dragons.

Source: CNN- 24 March 2009

Monitor Lizards on Military Runway in Florida

Reports of *Varanus niloticus* on the grounds of Homestead Air Reserve Base near Miami, Florida, US, have raised concerns for human health and safety, with monitor lizards occasionally seen basking on the runways of the base. According to Scott Hardin, exotic species coordinator for Florida's Fish and Wildlife Conservation Commision, *V. niloticus* began showing up near the air reserve base in 2008, and believes the population may be reproducing.

Source: National Geographic News- 19 May 2009

Malaysian Wildlife Officers Seize 210 Monitor lizards

Malaysian wildlife officers seized 210 *Varanus bengalensis nebulosu*s that were believed to be for sale at a village in the central Pahang state. A raid led by the Malaysian wildlife department resulted in the discovery of the *V. bengalensis nebulosus*, encased in individual sacks. The monitors were valued at around 10,500 ringgit ($2,837 USD). *Varanus bengalensis nebulosus* is a protected species in Malaysia and is highly sought after for its meat, which many Malaysians regard to have medicinal properties.

Source: Earthtimes.org- 20 April 2009

Indonesian Zoo Welcomes 32 Newborn Komodo dragons

The Surabaya Zoo, in Jakarta, Indonesia, has recently hatched 32 *Varanus komodoensis*. According to zoo officalis, 14 eggs are still currently incubating. Although *V. komodoensis* has been kept at the zoo since the early 1980s, this recent event has brought their total number of captives from 34 to 66 individuals.

Source: China Post- 23 March 2009

1,200 Monitor lizards seized

After a high-speed pursuit on the Kuantan-Gambang highway in Jalan Kuantan-Gambang, Malaysia on 8 April 2009, Pahang Wildlife and National Parks Department officers uncovered 1.200 *Varanus bengalensis nebulosus* in the back of the perpetrators' truck. According to officials, the driver and two assistants, aged between 37 and 50, traveled from Johor to purchase the lizards from the Orang Asli people in Jalan Kuantan-Gambang. A raid of a house at the Mencupu Orang Asli settlement the same day resulted in the seizure of 34 additional *V. bengalensis nebulosus*.

Source: New Straits Times- 14 April 2009

Omaha's Henry Doorly Zoo Hatches *Varanus gouldii*

Omaha's Henry Doorly Zoo, Nebraska, US, successfully hatched five *Varanus gouldii* in December 2008, At an average incubation temperature of 29.7 °C, the first hatchling emerged after 186 days, three weeks earlier than predicted. This reproductive event represents the zoo's first successful captive breeding of any varanid species.

Source: AZA Connect- June 2009

Varanus gouldii hatching. Omaha's Henry Doorly Zoo. Photograph by **Brandon Greaves**

ARTICLES

Biawak, 3(2), pp. 37-45

Monitoring the Trade: Using the CITES Database to Examine the Global Trade in Live Monitor Lizards (*Varanus* spp.).

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Abstract - Previous research has shown particular monitor lizard species to be the subject of intense exploitation for the global trade in reptile skins. However, to date there has not been a review of the CITES - declared trade in live monitor lizards. This paper examines the dynamics of the trade in live monitor lizards between 1975 and 2005, based on CITES import data to determine the countries involved, as both exporters and importers. In addition, the species involved in the trade and their source are explored. The results are then discussed with regards to the conservation implications of this trade.

Introduction

In the early 1990's the global trade in wildlife resources was estimated to exceed US$ 159 billion per year, of which approximately US$ 15 billion was accounted for by the trade in live animals and plants, as well as their constituent products and derivatives (Cowdrey, 2002). Reptiles and their constituent products have and continue to be, heavily exploited in many parts of the globe. Demands for reptile products have included skins (Jenkins and Broad, 1994; Thorbjarnarson, 1999), meat (Klemens and Thorbjarnarson, 1995) and ingredients for traditional folk medicine (Alves et al., 2008). As a result, significant historical over-harvesting has been implicated in the extinction of some reptile species, such as many giant tortoise populations of the Mascarene Islands (Stoddart and Peake, 1979).

A more recent demand has been for live reptiles destined for the exotic pet trade (Hoover, 1998), leading researchers to be concerned about the contribution over-exploitation may have upon the current global decline in reptiles (Gibbons et al., 2000). In fact, pressure from the trade in live reptiles has been implicated in the extirpation of both the Chinese cave gecko (*Goniurosaurus luii*) and the Roti Island snake-necked turtle (*Chelodina mccordi*) from their type localities soon after their formal description in the scientific literature (Stuart et al., 2006). Demand for live reptiles within the EU alone has resulted in an almost 400% increase in the number of animals imported from 60,000 animals in 1990 to 225,000 in 1999 (Engler and Parry-Jones, 2007), whilst the United States importation records reveal a trade of several million amphibians and reptiles on an annual basis (Schlaepfer et al., 2005).

Previous studies examining the trade in live reptiles destined for the pet market have been limited (but see Carpenter 2004; Ceballos and Fitzgerald, 2004; Schlaepfer et al. 2005; Turkozan & Kiremit, 2007) and have not included an analysis for the lizards of the varanid genus, despite the EU imposing import restrictions in 1997 of both live animals and their products for four species of monitor lizard (*V. dumerilii*, *V. jobiensis*, *V. beccarii* and *V. salvadorii*) from Indonesia (Engler and Parry-Jones, 2007). Whilst records exist within the Convention on International Trade in Endangered Species (CITES) trade database there have not been any attempts made to quantify the declared and therefore legal trade in live monitor lizards. As a result, this study was undertaken to examine the dynamics of the declared trade in live monitor lizards conducted over a 30 year period (1975-2005) using CITES import data.

Data Source

Data comprising details of the trade in live specimens of all CITES listed varanids were downloaded from the CITES trade database as a compiled Comparative Tabulation Table from UNEP/WCMC (http://www.cites.org/eng/resources/trade.shtml). The data comprised information on the number of individuals of each varanid species imported and exported by countries involved in the trade between 1975 and 2005. In addition, all records from 1990 onwards contained information regarding the origin of those animals. Data reported by importing countries was used to calculate estimates of the numbers exported by individual countries. Import data was used in preference to export data since it is based on CITES permits that are actually used, whilst export data is typically based on CITES permits that are issued, some of which may not be used (Carpenter et al., 2004).

Results

Species traded

Forty-two different species of monitor lizard were exported as live animals for commercial purposes between 1975 and 2005, totalling 1,347,618 specimens. The number of species involved in the trade increased to peaks of 28 species in both 2002 and 2005 (Fig. 1). Despite the high number of species involved in the trade, 91% of all animals exported during the thirty year period were of just three species (Fig. 2); *Varanus. exanthematicus* (48.1%, *n* = 647,600), *V. niloticus* (23%, *n* = 309,759) and *V. salvator* (19.6%, *n* = 263,750). Only four other species constituted an individual contribution to the trade in excess of one per cent (Table 1).

Countries involved in the live monitor trade

Based on CITES import data a total of 82 countries were recorded as having exported live monitor lizards between 1975 and 2005. This figure includes a number of countries outside the global distribution of wild monitor lizards and included exports of captive-bred individuals as well as re-exports of wild caught animals. Only nine of the 82 countries contributed in excess of

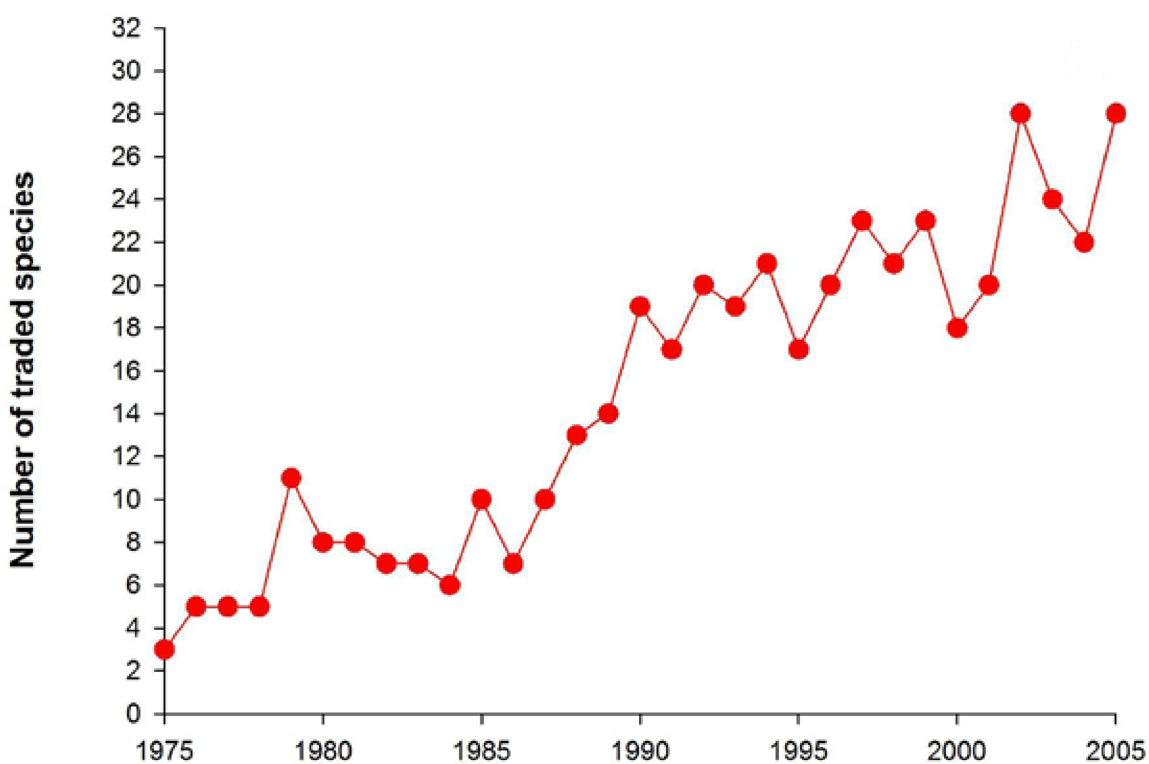

Fig. 1. The number of monitor lizard species exported annually as live animals for commercial purposes between 1975 and 2005.

Table 1. The number of countries involved in the exportation of live monitor lizards between 1975 and 2005 as recorded by CITES trade data.

Species	Number of exporting countries	Total number of exported lizards	Percentage of global trade
Varanus spp.	23	8,962	0.6650%
Varanus acanthurus	11	1,690	0.1254%
Varanus albigularis	14	26,079	1.9352%
Varanus bengalensis	4	148	0.0110%
Varanus bogerti	3	1,211	0.0899%
Varanus caudolineatus	1	22	0.0016%
Varanus doreanus	8	3,907	0.2899%
Varanus dumerilii	15	14,380	1.0671%
Varanus exanthematicus	48	647,600	48.0552%
Varanus gilleni	4	41	0.0030%
Varanus glauerti	2	88	0.0065%
Varanus glebopalma	1	1	0.0001%
Varanus gouldii	6	116	0.0086%
Varanus griseus	2	100	0.0074%
Varanus indicus	15	19,049	1.4135%
Varanus jobiensis	9	5,538	0.4109%
Varanus kingorum	3	33	0.0024%
Varanus komodoensis	1	14	0.0010%
Varanus macraei	2	631	0.0468%
Varanus melinus	2	1,134	0.0841%
Varanus mertensi	2	96	0.0071%
Varanus mitchelli	1	5	0.0004%
Varanus niloticus	46	309,759	22.9857%
Varanus olivaceus	4	19	0.0014%
Varanus ornatus	1	6	0.0004%
Varanus panoptes	4	5,512	0.4090%
Varanus pilbarensis	1	17	0.0013%
Varanus prasinus	14	7,497	0.5563%
Varanus rosenbergi	1	3	0.0002%
Varanus rudicollis	16	16,266	1.2070%
Varanus salvadorii	11	3,376	0.2505%
Varanus salvator	35	263,750	19.5716%
Varanus semiremex	1	35	0.0026%
Varanus similis	5	2,140	0.1588%
Varanus spenceri	1	1	0.0001%
Varanus storri	4	188	0.0140%
Varanus timorensis	9	7,973	0.5916%
Varanus tristis	4	166	0.0123%
Varanus varius	3	4	0.0003%
Varanus yemenensis	3	33	0.0024%
Varanus yuwonoi	1	28	0.0021%
Total	**82***	**1,347,618**	**100%**

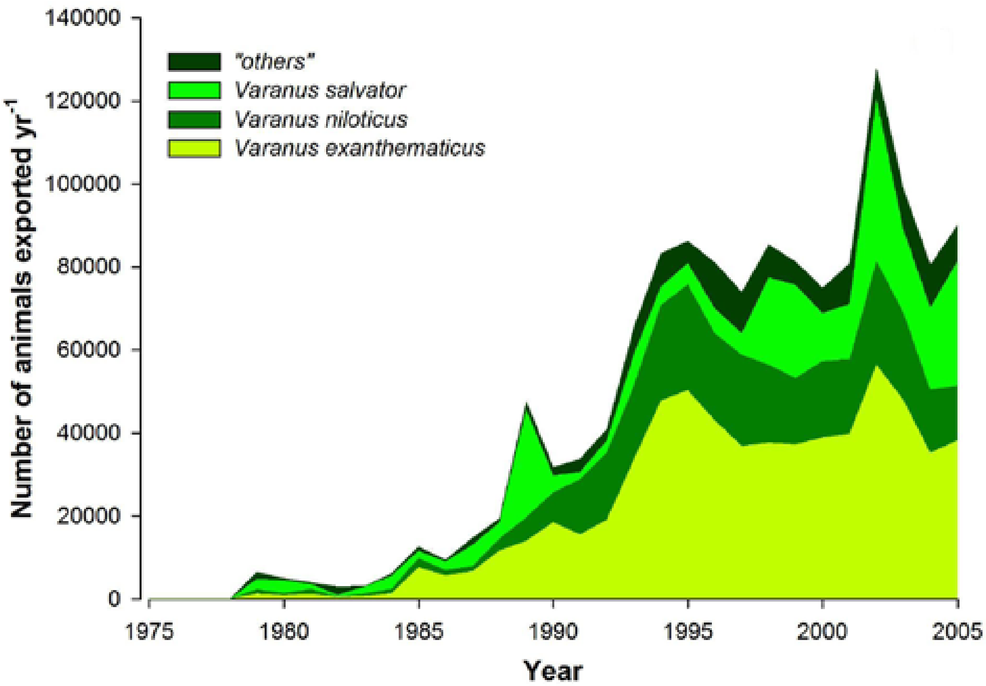

Fig. 2. The number of individuals exported annually as live animals for commercial purposes between 1975 and 2005.

1% of the total number of live animals traded (Fig. 3a). Four African nations, four Asian nations and the United States accounted for 94.3% of all live animals exported (Table 2.). It should be noted that despite accounting for over 1% of the total trade in live monitor lizards each, Thailand and the Philippines have not exported any monitor lizards since 1992 and 1994 respectively.

Between 1975 and 2005 a total of 89 countries submitted records to CITES documenting the importation of monitor lizards. However, imports were dominated by 10 countries, with the greatest number of live monitor lizards entering the United States (68%; *n* = 915,793 lizards; Fig. 3b). Three Asian countries (Hong Kong 5.8%; Japan 5.3%; China 2.6%), five European countries (Germany 3%; Great Britain 2.6%; Spain 1.7%; France 1.5%; Netherlands 1.1%) and Canada (1.8%) constituted a further 25.4% of the total importations over the 30 year period (Figure 3b).

Sources of monitors in the live trade

Data on the monitor lizards found in the international trade prior to 1990 does not include their origin. However, this data was available from 1990 until the end of 2005 (Table 3). For the two most heavily traded species (*V. exanthematicus* and *V. niloticus*) there has been a steady decline in the proportion of animals exported globally that were declared to be wild caught from 100% in 1990 to lows of 49.5% (2004) and 27.2% (2005) respectively. For both species the proportion of lizards that were reported as farmed or ranched showed a correspondingly steady increase (Fig. 4a and 4b). In contrast, the declared origin of the third most heavily traded live species, *V. salvator*, has remained almost exclusively wild caught, with small amounts of captive bred animals declared in 1996 and 1997 (1.3% and 1% of the annual trade respectively) and in 2005 lizards declared as ranched/ farmed (2.7% of the annual trade; Fig. 4c). Additionally there has been a steady decline in the number of animals reported as wild caught for all other *Varanus* spp. to a low of 49% in 2005 with corresponding increases in the number of animals reported as captive bred and ranched (30.5% and 20.5% respectively).

Discussion

Despite a total of 42 *Varanus* spp. being traded, the results of this review show exports of live animals between 1975 and 2005 to clearly be dominated by three species, with the majority of these animals exported by just nine countries. The four major exporting countries in Africa (Benin, Ghana, Togo and Tanzania) involved in the trade in live monitor lizards are also known to be significant contributors to the global trade in Chameleons (Carpenter et al., 2004) suggesting a reliance on wildlife as a significant economic resource (Roe et al., 2002). This

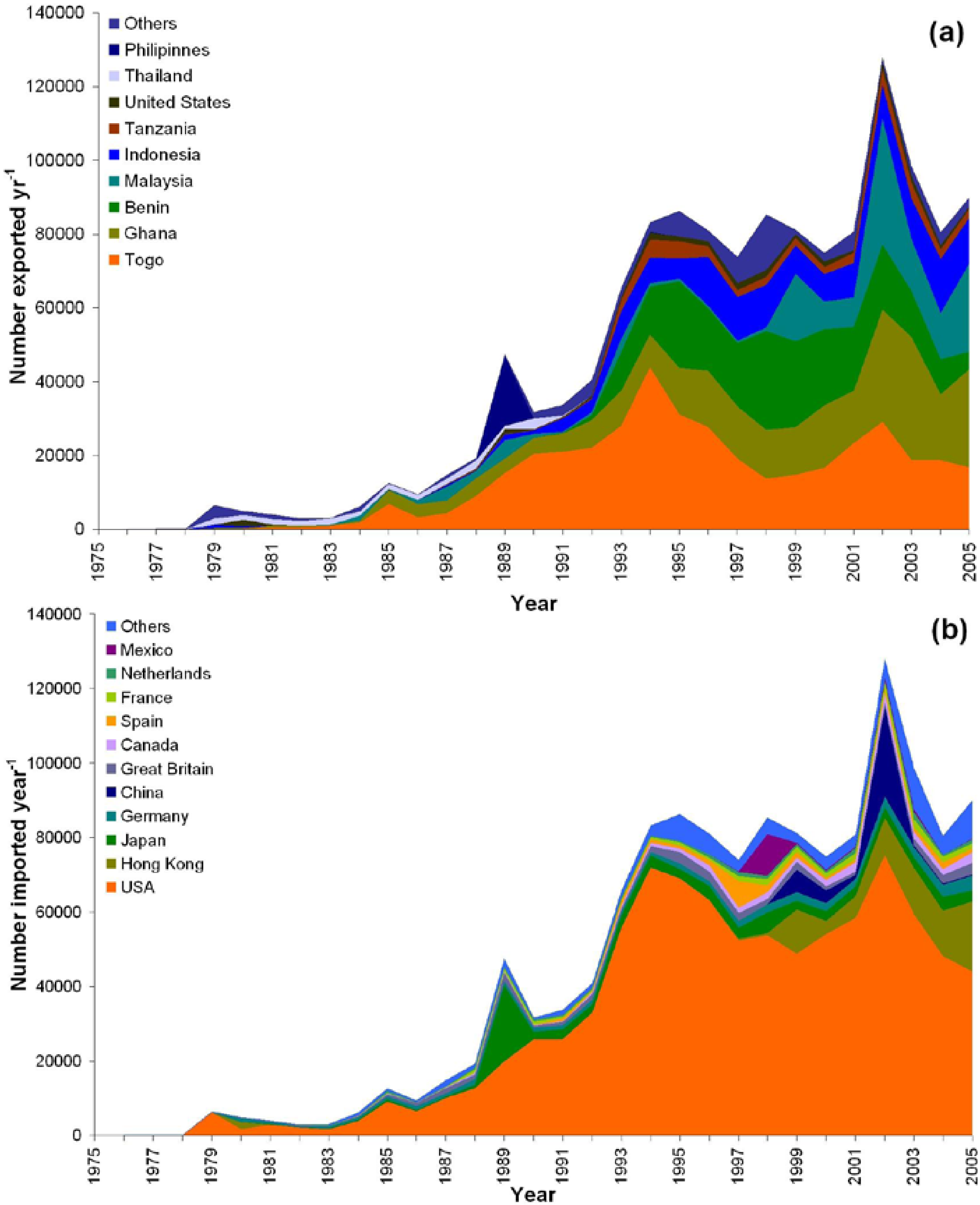

Fig. 3. The number of live monitor lizards exported (a) and imported (b) between 1975 and 2005 by individual countries, as reported in CITES trade data.

Table 2. Exports of live monitor lizards by the nine countries contributing in excess of one percent of animals to the global trade.

Country	*Varanus exanthematicus* No. lizards exported	*Varanus exanthematicus* Percentage of species' total trade	*Varanus niloticus* No. lizards exported	*Varanus niloticus* Percentage of species' total trade	*Varanus salvator* No. lizards exported	*Varanus salvator* Percentage of species' total trade	*Other Varanus* spp. No. other spp. Exported	*Other Varanus* spp. No. lizards exported	*Other Varanus* spp. Percentage of species' total trade
Benin	122,800	19	90,812	29.3	-	-	0	-	-
Ghana	254,770	39.3	8,427	2.7	-	-	0	-	-
Togo	243,598	37.6	164,167	53	-	-	0	-	-
Tanzania	5,404	0.8	15,844	5.1	24	0.009	1	19,770	15.8
Indonesia	202	0.03	28	0.009	66,524	25.2	25	73,006	57.8
Malaysia	7	0.001	-	-	138,363	52.4	14	3,310	2.6
Philipines	-	-	3	0.0009	18,719	7.097	6	118	0.1
Thailand	-	-	10	0.003	17,327	6.56	8	2,196	1.7
United States	9,575	1.47	6,326	2.04	4,345	1.65	24	1,825	1.5
Total	**636,356**	**98.201**	**285,617**	**92.1529**	**245,302**	**92.916**		**100,225**	**79.5**

Table 3. Sources of live monitor lizards legally traded between 1990 and 2005 as recorded in the CITES trade database (CB = Captive Bred, R = Ranched or farmed lizards and WC = Wild Caught).

	V. exanthematicus			*V. niloticus*			*V. salvator*			*All other Varanus* spp.		
Year	CB	R	WC	CB	R	WC	CB	R	WC	CB	R	WC
1990	0	0	13,567	1	0	4,309	0	0	3,884	8	0	1,712
1991	0	0	14,389	0	0	7,230	0	0	1,073	17	0	1,881
1992	0	0	16,220	0	0	13,444	0	0	2,232	13	0	2,483
1993	866	0	30,165	67	0	13,629	0	0	5,359	18	0	4,778
1994	1,216	25	44,445	452	0	20,760	0	0	3,685	52	0	5,742
1995	855	115	45,007	609	325	22,754	19	0	4,270	176	0	2,585
1996	2,145	1,195	35,549	1,243	1,564	16,178	40	0	2,960	140	0	4,180
1997	4,191	1,657	24,368	4,001	1,003	8,459	24	0	2,272	232	4	3,514
1998	1,898	1,636	22,468	1,160	997	8,750	25	0	18,331	56	90	4,009
1999	1,250	6,236	19,701	690	4,737	6,454	1	3	14,660	52	136	3,434
2000	415	8,135	18,158	170	6,399	4,937	0	0	9,689	236	2	3,555
2001	253	15,307	21,351	0	7,879	7,366	7	7	9,210	448	87	4,907
2002	6	14,916	31,679	0	8,514	8,597	2	23	37,461	841	368	4,778
2003	131	13,546	24,650	74	14,041	5,988	0	75	14,397	719	472	4,780
2004	20	15,850	15,572	0	8,678	3,991	4	20	11,835	812	479	3,553
2005	0	12,696	15,329	87	6,842	2,595	0	586	21,295	1,712	1,146	2,754

is likely to be a similar story for the two Asian countries (Malaysia and Indonesia) that continue to export large numbers of monitor lizards, as both live animals and their constituent products, which raises questions about the sustainability of this trade.

Intensive collection of animals may have significant impacts on local populations. Selective harvesting of larger male *V. salvator* is known to occur for the skin trade in Sumatra (Shine et al., 1996) and may also occur with the live animal trade, with exporters potentially favouring smaller individuals and juveniles due to reduced transportation costs. Selective harvesting may also have a negative effect on future population recruitment. However, it should be noted that although almost 1.4 million live monitor lizards were traded during the 30 year period reviewed, this number pales when compared to the estimated 2.3 million animals that are killed annually to supply the international leather industry (Jenkins and Broad, 1994). Despite such intensive collection of animals for the skin trade, Shine et al. (1996) argue that a number of characteristics such as ecological flexibility and high reproductive rate of varanid lizards and, in particular *V. salvator*, allow them to withstand such high rates of harvest. Further work examining the ecological traits of monitor lizards destined for the pet trade is required before a definitive answer on the sustainability of collecting can be ascertained (Iskandar and Erdelen, 2006). In particular, naturally rare species that have limited distributions may be significantly impacted by even low levels of harvesting. This is particulary important for monitor lizards known to be endemic to small islands, for example *V. beccarii* and *V. melinus,* whose populations are unlikely to be able to withstand intensive harvesting. Studies of *V.*

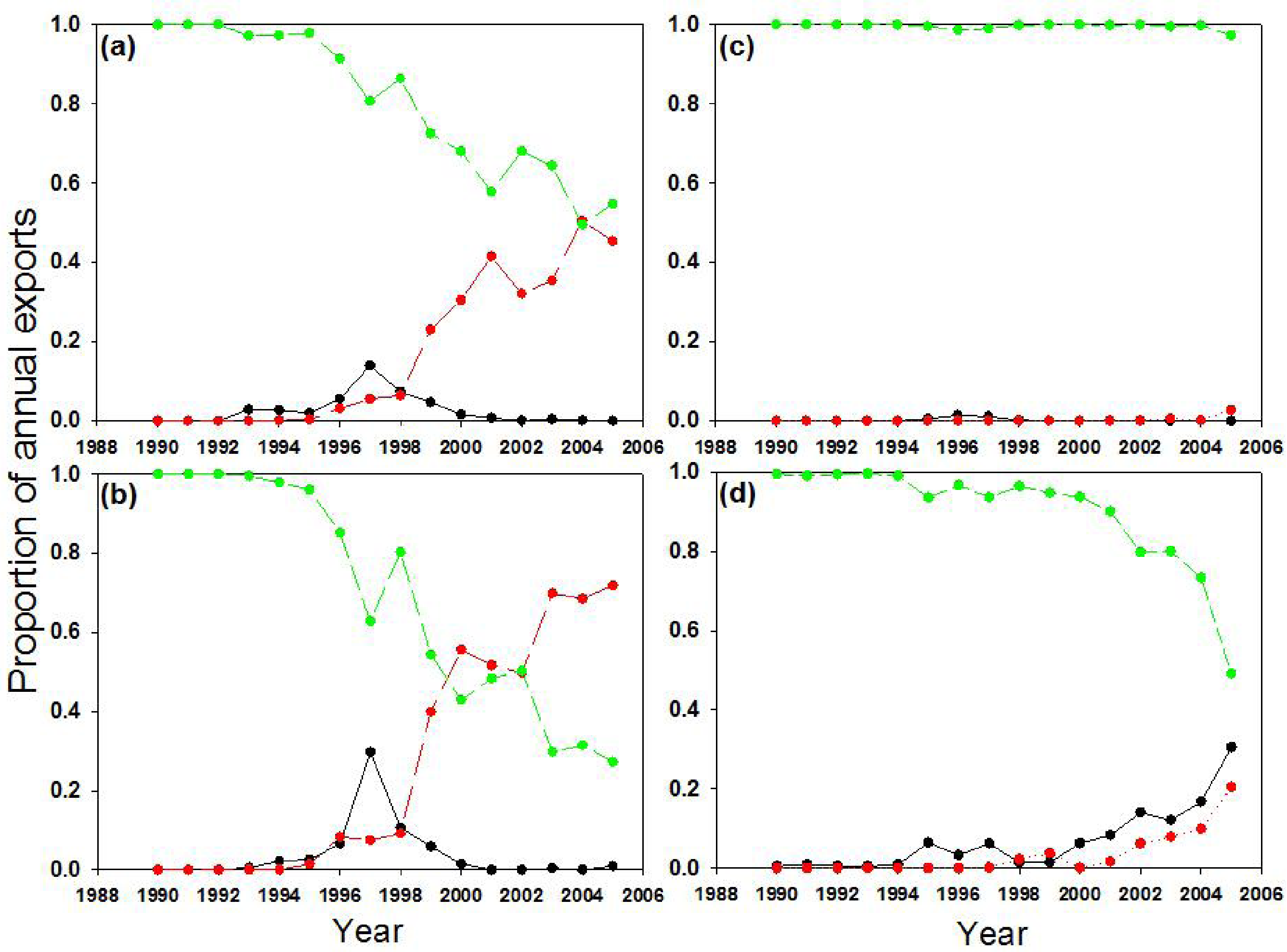

Fig. 4. Trends in the annual proportions of wild caught (green), ranched and farmed (red) and captive bred (black) live monitor lizards in the global commercial trade. Panels refer to; *V. exanthematicus* (a), *V. niloticus* (b), *V. salvator* (c) and all remaining *Varanus spp*. (d)

exanthematicus in the coastal plains of Ghana have shown individual collectors to remove approximately 50% of all juveniles they encounter (Bennett, 2000). If such collecting practices were to be applied to monitor species of small population size known to be endemic to single islands, it could result in their extirpation, as has been seen with other reptile species collected for the pet trade (Stuart et al., 2006).

One important result this review has highlighted is the large increases in the numbers of monitors declared to be ranched/ farmed and captive bred that have entered the trade. Verifying such declarations is not possible, and may be spurious. Such changes in the source of live animals maybe an attempt by exporters to ensure a sustainable supply of animals. However, altering consignment labels is known to occur in attempts to thwart national or international trade controls (Roe et al., 2002) and since governance of the pet trade lags behind that of the leather industry, the extent to which such actions occur remains unknown (Carpenter et al., 2005). The process of ranching/farming monitor lizards also raises other concerns. Typically, this involves the capture of gravid females or the collection of eggs from fresh nests. The eggs are then incubated and the resultant young exported, whilst the females are released en masse, often at a single locality (Bennett, 2001). Clearly this raises questions with regards to the large-scale removal of cohorts from a population, as well as the potential for altering population sex-ratios through the translocation of reproductively active females.

From the data reviewed it may appear that the trade in live monitor lizards for the pet trade may have limited consequences for the conservation of the three most commonly traded species in comparison to the levels of their harvesting for the leather trade. However, there have been further conservation implications raised by the trade in live monitor lizards such as the establishment of feral populations outside their natural range. *Varanus niloticus* is known to have established a breeding feral population in the Cape Coral region of Florida which has the potential to impact numerous native species due to its carnivorous nature (Enge et al., 2004). In addition traded reptiles have the potential to introduce novel parasites such as ticks and their subsequent zoonoses into areas that were previously out with their distribution (González-Acunã et al. 2005). Diseases that are of significance to both animals and human populations have been linked to the trade in wildlife including; SARS and the trade in small mammals (Bell et al., 2004), Chytrid fungus and the trade in *Xenopus spp*. (Weldon et al., 2004) and Avian Influenza (Karesh et al., 2007) Whilst the current trade in live monitor lizards has not been linked with the movement of any infectious diseases, the established routes also have the potential to increase the spread of any potential future outbreak.

In summary, this review has shown that the trade in live monitor lizards is dwarfed by that of the leather industry and suggests that the source of animals is shifting from wild caught populations to captive-bred and ranched/farmed animals. The fact that this study has solely relied on data made available in the CITES trade database suggests that all figures are likely to be under-estimates of the total trade in live animals. Data from countries that are not signatories of the CITES agreement, in addition to data from the illegal trade are unavailable. In addition many mis-matches in reporting of lizards between importing and exporting countries occur (Kenneth McCloud, *pers. comm.*), which suggests further work is required to improve future CITES reporting. Clearly more research is required to examine the ecological characteristics of wild populations that are still being exploited for the trade in live animals. In addition the sustained levels of trade in live animals suggest a need for further research examining the effectiveness and implications of the ranching and farming activities of exporting nations in ensuring a sustainable future for this trade.

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Ecological Function of Venom in *Varanus*, with a Compilation of Dietary Records from the Literature

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Abstract - Until recently, venom in reptiles was thought to be present in two lineages: Serpentes and *Heloderma*. Research has now shown that venom evolved only once in reptiles, in a venom clade known as Toxicofera. This has resulted in venoms being discovered in many more species within this clade, including monitor lizards, genus *Varanus*. To date, very little work has been published on the ecological function of venom in monitor lizards. More generally, venom can fulfill four functions: defence, prey capture, aiding digestion, and maintaining oral hygiene through antimicrobial effects. Although more than one function may be served by the venom of any given species, in most cases one of these is more important than others, i.e., the primary function. Previous evidence for prey capture as the primary function of venoms has often used data on wild prey to assist interpretation, and as a result, a compilation of wild monitor lizard diets is presented. Subsequently, speculations on the primary function of *Varanus* venoms are made and discussed. Although many data are needed to support or refute many of the points discussed, I suggest that an enhancement of digestive function may be an important element of the venom, possibly the primary function in at least some species. The suggestions are made with the aim of encouraging future work to empirically test the hypotheses which derive from the ideas herein. Only in this way can we hope to further our knowledge on the ecology of venom in reptiles.

Until recently, the prevailing view was that reptile venoms were restricted to two clades of extant squamates: Serpentes and *Heloderma* (Minton and Minton, 1969; Pough et al., 2004). Effects of the toxins from *Varanus* have usually been ascribed to bacterial infections caused by a virulent oral bacterial flora (Gillespie et al., 2002), but recent systematic and toxinological analyses have discovered the presence of venom glands and venom in *Varanus* (Vidal and Hedges, 2005; Fry et al., 2006). It should be borne in mind that only few *Varanus* species have been examined in this way (*V. acanthurus*, *V. mitchelli*, *V. panoptes rubidus*, and *V. varius*), but *V. griseus*, *V. komodensis* and *V. scalaris* bites on humans have also shown signs consistent with envenomation (Sopiev et al., 1987; Ballard and Antonio, 2001; Fry et al., 2006; Fry and Scheib, 2007). However, the early evolution of toxins relative to the origin of the genus and the widespread presence of venom in the clade containing it suggest that toxins are likely a ubiquitous character in monitor lizards.

This research has led to the naming of a clade including all anguimorph lizards, iguanian lizards, snakes, and the most recent common ancestor of these three clades (Vidal and Hedges, 2005). This clade has been called Toxicofera, and basal toxicoferan toxins include AVIT, B-type natriuretic peptide (BNP), Cysteine-rich Secretory Protein (CRISP), Cobra Venom Factor (CVF), Kallikrein, Nerve Growth Factor (NGF), Crotamine, Cystatin, and Vespryn (Fry et al., 2006; Fry and Scheib, 2007). The latter three toxins appear to be secondarily lost in varanids, but to the other six toxins listed above can be added Phospholipase A_2 (type III; PLA_2) (a basal anguimorph toxin) to give the currently known composition of varanid venoms. It is possible that additional toxins unique to *Varanus* or species within the genus are yet to be discovered, as only a few species have been examined. Likewise, variation in venom composition between species is likely to occur, but has thus far been poorly documented.

What research has so far been published is still in its preliminary stages, and has focussed on the pharmacology, toxicology, toxinology, molecular evolution, and systematic implications of varanid venom, but its natural history has for the most part been ignored. The only other paper of which I am aware that discusses the ecology of *Varanus* venom is an abstract from a presentation at the 6th World Congress of Herpetology (Fry, 2008). This highlights that, at least in *V. komodoensis*, venom may be importance in subduing prey as neither bite force nor pathogenic bacteria were found to be effective in prey capture. It also demonstrated that significant quantities of venom may be produced at least in some species, and so that these may be ecologically relevant. In this paper I offer speculations on the ecological function of venom in monitor lizards, in the hope that future work may empirically test these ideas and further our knowledge of the ecology of reptile venoms.

Function of Venoms

Toxins are taxonomically widespread in animals, and reptile venoms consist of a cocktail of different toxins, and so the venom as a whole may not be, and probably is not in most cases, restricted to one use (Russell, 1983; Kardong, 1996). Four main functions, which are not mutually exclusive, have previously been attributed to reptile venoms: a defensive mechanism (Russell and Bogert, 1981; Greene, 1997, p. 110), as an aid to digestion of prey (Thomas and Pough, 1979; Rodriguez-Robles and Thomas, 1992; McCue, 2005), to assist in the maintenance of oral hygiene via an antimicrobial effect (e.g. Stiles et al., 1991; Blaylock, 2000; Sachidananda et al., 2007; Ciscotto et al., 2009), or to assist in prey capture by killing or immobilizing prey. This last function is by far the most commonly implicated in a variety of animals including such divergent taxa as cnidarians and even mammals (Tomasi, 1978; Martin, 1981), as well as reptiles. Although more than one of these hypotheses may hold true for a given species, in most cases it is likely that one of them will be more important than the others, serving a primary function although other benefits may also be afforded by the venoms.

In squamate taxa, as currently known, only spitting cobras and *Heloderma* are specialised for the functional use of venom for defensive purposes. *Heloderma* largely prey on eggs, a diet known to lead to reduction of venom apparatus in other reptiles (Heatwole, 1999), and these lizards have certain components of their venom seemingly highly tailored for a defensive role (Beck, 2005). Although spitting cobras are specialised for defensive use of venom, they also use venom for prey capture, so in this case both defence and prey capture are likely to be important functions. Therefore, as currently understood, defence is an infrequent primary function of venom in reptiles. Associations suggestive of the use of venom for prey capture are common, and include an ontogenetic shift in both venom characteristics and diet (Andrade and Abe, 1999; Mackessy et al., 2003), substantial differences in venom amongst closely related species with different diets (Sanz et al., 2006), regression of the venom apparatus and a vast reduction in venom toxicity for ovophagous species that are part of highly toxic clades (Heatwole, 1999), and geographic variation in venom that may be explained by variation in diets (Glenn et al., 1983; Daltry et al., 1996, 1997).

The toxicity of any given venom can vary greatly between 'prey species' (Mebs, 2001), which may be a result of a predator-prey arms race. For instance, prey will be under strong selection pressure to evolve resistance to a predator's venom, potentially rendering them less susceptible to the effects of these toxins over time. Conversely, if a predator preys largely on insects, the toxins contained in its venom may be specific to insects and so have little effect on other prey types. This close relationship between the predator's venom and its effect on prey further supports the importance of venom for prey capture. Because of this, the following section will comment on the diets of monitor lizards to enable better evaluation of the function of venom within this lineage.

Diet of Varanid Species

The diet of monitor lizards is reported for many species, and as a group they have a variety of trophic modes, such as carnivory, insectivory, herbivory and frugivory. Gaalema (2007) assessed the prey choice for a collection of captive *Varanus*, including *V. komodoensis, V. rudicollis,* and *V. griseus*, by assigning preference scores using a method formulated by Ciccone et al. (2005). He found the strongest preference was for mice in all three species, but the two other prey items tested demonstrated variable preference scores between the species. *V. komodoensis* preferred avian prey (chicks) to fish, and *V. griseus* showed a preference for eggs over fish, but neither of these latter two preferences appear particularly strong. Two individuals of *V. rudicollis* selected fish over crickets, and this seems a relatively strong preference, but a third specimen had a slightly higher preference for crickets, but this seemed low. A survey of the diets of *Varanus* species taken mainly from the primary literature is presented in Table 1. As can be seen, many of the smaller species prey largely on insects whereas larger species select more mammalian and reptile prey items. Note that 'small' and 'large' are used somewhat subjectively here, in that no absolute size is given as a cut-off between these categories, however, they serve as a guide relative to the range of sizes in the genus (e.g. *V. prasinus* is small, *V. salvator* is large). While exceptions to this do exist, the data compiled here from a number of dietary studies in natural settings suggest a greater importance of vertebrate prey in larger species as compared with smaller species. Importance is a difficult term to define, as Losos and Greene (1988) found that while mammals may comprise a relatively small proportion of the number of prey in some species, they are still important in terms of the proportion of dietary energy they provide. An attempt has been made here to evaluate importance for use in Table 1, but these limitations should be borne in mind. In addition, aquatic prey items are common components in the diet only in those species exhibiting more aquatic habits, as may be expected.

Possible Functions of *Varanus* Venoms

To return to the four previously mentioned functions of reptile venoms, although they are not mutually exclusive, as a means to explain the primary function of the venom the defensive hypothesis seems least likely, despite its obvious utility in the closely related *Heloderma*. The unusual situation in this genus is thought to be primarily the result of the relatively poor escape capabilities of gila monsters and beaded lizards (Beck, 2005), a situation which does not hold true for monitors. The presence of kallikrein in the venom (known to be a key cause of pain in other lizard venoms) may provide some weak support for a defensive role. Alternatively, these may serve other roles (e.g. as an aid to immobilize prey), or may simply be inherited from an evolutionary ancestor, but now unimportant in *Varanus*, albeit this is unlikely due to the energetic costs of producing venom (McCue, 2006). Therefore, assuming this suggestion is correct, the function of *Varanus* venom is likely to be related to the processing of prey in some way – either acting in the procurement of prey and/or assisting the digestive process. Note that the possibility of a role in oral health is not discussed further, and this is due to a lack of any studies of any antimicrobial properties of *Varanus* venom. However, this seems unlikely as a diverse oral flora has been documented from *Varanus* (Gillespie et al., 2002).

For venom to serve the primary function of dispatching prey, it must clearly bestow an advantage over not using venom, particularly as it is metabolically expensive to produce (McCue, 2006). Two key aspects of the ecology of the lizard are important in the evaluation of this hypothesis – diet and foraging tactics. For those monitors preying chiefly on groups such as insects, other invertebrates and eggs, it is difficult to see the advantage that using venom to subdue prey would give because, for example, eggs do not need subdued and the massive size difference between even the smaller monitors and their invertebrate prey allows them to be quickly and efficiently overpowered in at least most circumstances. The same is likely true for those that prey on relatively small reptiles, such as other lizards, but those monitors that do prey on potentially dangerous prey, such as many mammals or venomous species could conceivably gain an advantage from the venom. The powerful jaws of *Varanus*, however, allow the crushing of prey items small enough to be taken, often resulting in a quick death and so minimal risk of injury. One exception worth mentioning in this regard is *V. komodoensis*, which regularly preys on large mammals (with greater body size than the lizard). Prey falling into this category may well pose a risk to the predator, so could venom serve the primary role of assisting safe capture of prey in *V. komodoensis*? The foraging tactics of this large monitor make it unlikely. When hunting for large mammals, the Komodo monitor employs ambush tactics by lying in wait for passing prey before attacking and typically taking one large bite which causes extensive bleeding and severs tendons, both of which act to cripple the prey with minimal risk to the lizard (Auffenberg, 1981; King et al., 2002). With these massive injuries caused by the teeth and jaw musculature, which often lead reasonably quickly to incapacitation of the prey, it again becomes difficult to see an advantage here in producing venom for prey capture. Although virulent bacteria is transferred to prey during the bite, this is likely incidental and not a deliberate tactic by the monitor, and the quantity of blood lost from the injuries inflicted is likely enough to disable the prey even without these bacteria. However, this last point is difficult to test adequately using experimental methods, and so no data are available to confirm this suspicion. Nevertheless, Fry (2008) did propose a role of venom in prey capture, and although he did not examine other possible functions of the venom, this deserves further study in *V. komodoensis*.

While any analysis of the toxins in *Varanus* venom could potentially be complicated by bacterial toxins (in the manner of more traditional schools of thought), toxinological analysis would reveal the nature of the toxins, which are very different between toxicoferans and bacteria (cf. Arni and Ward, 1996; Snijder and Dijkstra, 2000). The author predicts that, at least in terms of any possible role in prey capture, bacterial infection will eventually prove to be of limited importance due to the effect on prey species noted from the venom (Fry et al., 2006) and the effects of massive blood loss from bites, but further work is needed to confirm this suspicion.

Finally, therefore, how probable is the hypothesis that the primary function of venom in monitor lizards is to enhance digestion of prey? Given that *Varanus* often consume large meals in relation to their body size, it is likely that an increase in the speed and/or efficiency of digestion would be selected for, particularly where prey items have a relatively rounded cross section, such as vertebrates (a common component of wild monitor diets [see table 1]). Further support may be found in the composition of the venom. Fry et al. (2006) found that PLA_2 has evolved in the anguimorphan clade subsequent to the evolution of the basal toxicoferan toxins. Venom phospholipases can act as potent neurotoxins, but also function in the breakdown of molecules in a way that assists digestion of prey items (Condrea and de Vries, 1965; Harris, 1997), and this latter action, if shown to be the case for *Varanus* venom, renders it highly plausible that it is well suited to the enhancement of prey digestion. Coupled with the problems discussed above for other explanations, I suggest that the primary function of venom in monitor lizards is to increase the speed and/or efficiency of digestion. Future research should aim to test this hypothesis experimentally by comparing digestion of prey items with or without the influence of *Varanus* venom.

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Appendix

Table 1. Published diets of monitor lizards. Items are listed in descending order of importance as far as can be ascertained.

Varanus sp.	**Dietary Items**	**Reference**
acanthurus	Insects, reptiles, other invertebrates, plant material	King, 2008
albigularis	Other invertebrates, insects, reptiles, amphibians, birds, bird eggs, mammals	Branch, 1991; Bennett, 1998
baritji	Other invertebrates (mainly theraphosid spiders)	King, 2004
beccarii	Other invertebrates (mainly crabs), reptiles, amphibians	de Lisle, 1996; Bennett, 1998
bengalensis	Insects, other invertebrates, reptile eggs, mammals, reptiles, bird eggs, amphibians, fish, birds	Auffenberg, 1994; Bennett, 1998; Pianka, 2004a; Liu, 2007
brevicauda	Insects, other invertebrates, reptiles, reptile eggs	Pianka, 1970a, 1994; King and Pianka, 2007
caerulivirens	Other invertebrates, insects, amphibians	Ziegler, Böhme and Philipp, 2004; Philipp, Ziegler and Böhme, 2007
caudolineatus	Insects, reptiles, other invertebrates, plant material	Pianka, 1969
cerambonensis	Other invertebrates, insects, reptiles, reptile eggs	Philipp, Ziegler and Böhme, 2004a; Philipp, Ziegler and Böhme, 2007
doreanus	Reptiles, reptile eggs (mainly turtle eggs), insects	Bennett, 1998; Philipp, Ziegler and Böhme, 2007

Table 1. *Continued*

Varanus sp.	**Dietary Items**	**Reference**
eremius	Reptiles, insects, other invertebrates, mammals, seeds	Pianka, 1968, 2004b, 2007
exanthematicus	Insects, mammals, birds, reptiles, bird eggs, other invertebrates, amphibians	Yeboah, 1993; de Lisle, 1996; Bennett, 1998
finschi	Reptiles, insects, birds, other invertebrates	Philipp, Ziegler and Böhme, 2004b; Philipp, Ziegler and Böhme, 2007
flavescens	Amphibians, reptile eggs, insects, other invertebrates, mammals, birds, bird eggs	Bennett, 1998
flavirufus	Mammals, reptiles, reptile eggs, insects, fish, other invertebrates, birds, bird eggs, amphibians	Bennett, 1998
giganteus	Reptiles, mammals, insects, other invertebrates, reptile eggs, birds	Pianka, 1994; Bennett, 1998; Macdonald, 2007
gilleni	Reptiles, insects, other invertebrates, bird eggs, mammals	Pianka, 1969, 1982; de Lisle, 1996; Horn, 2004
glauerti	Insects, other invertebrates, reptiles, reptile eggs	de Lisle, 1996; Sweet, 1999
glebopalma	Reptiles, other invertebrates, insects, amphibians	de Lisle, 1996; Bennett, 1998; Sweet, 1999
gouldii	Insects (mainly caterpillars or beetles), reptile eggs, other invertebrates, reptiles, amphibians, mammals, fish, birds, birds eggs	Pianka, 1970b; Shine, 1986; Thompson, 2004
griseus	Mammals, birds, reptiles, eggs, amphibians, insects, other invertebrates	Stanner and Mendelssohn, 1987; Bennett, 1998
indicus	Other invertebrates (mainly crabs), insects, reptile eggs, fish, reptiles, birds, bird eggs, mammals	de Lisle, 1996; Philipp, Ziegler and Böhme, 2007
jobiensis	Insects, amphibians, other invertebrates, reptile eggs	Philipp, Ziegler and Böhme, 2004c; Philipp, Ziegler and Böhme, 2007
keithhornei	Insects	Irwin, 1994; Bennett, 1998
kingorum	Insects	Bennett, 1998
komodoensis	Mammals (mainly large species such as boar and deer), eggs, birds, reptiles, insects	Burden, 1928; Auffenberg, 1981; King et al., 2002

Table 1. *Continued*

Varanus sp.	**Dietary Items**	**Reference**
mabitang	Fruit, leaves, seeds, insects, other invertebrates	Gaulke, 2004; Gaulke et al., 2007
melinus	Insects, amphibians, bird eggs	Ziegler and Böhme, 2004
mertensi	Other invertebrates (mainly crustaceans), insects, fish, amphibians, reptile eggs, mammals, reptiles, birds, fruit	Mayes, 2006
mitchelli	Insects, fish, other invertebrates, reptile eggs, amphibians, reptiles, mammals, birds	Shine, 1986
niloticus	Other invertebrates (mainly gastropods and crustaceans), insects, reptiles, fish, mammals, bird eggs, amphibians	Yeboah, 1993; Bennett, 1998; Luiselli et al., 1999; Lenz, 2004
olivaceus	Fruit, other invertebrates (primarily molluscs), insects, birds, bird eggs	Auffenberg, 1988; Bennett, 1998
ornatus	Other invertebrates (mainly crabs), reptiles	Böhme and Ziegler, 2004
panoptes	Insects (mainly crickets), amphibians, other invertebrates, reptiles, reptile eggs, mammals, fish, birds	Shine, 1986; Shannon, 2008
pilbarensis	Insects, other invertebrates, reptiles	de Lisle, 1996
prasinus	Insects, other invertebrates, mammals	Greene, 1986
primordius	Reptiles, reptile eggs, insects	Bennett, 1998; Husband and Christian, 2004
rosenbergi	Mammals, insects, reptiles, other invertebrates, amphibians, birds	Bennett, 1998; King and Green, 1999
rudicollis	Insects, other invertebrates, amphibians	Bennett, 1998
salvadorii	Birds, bird eggs, mammals	de Lisle, 1996; Bennett, 1998
salvator	Mammals, insects, other invertebrates, reptiles, birds, amphibians, fish, birds eggs, reptile eggs	Gaulke, 1991; Bennett, 1998; Shine et al., 1998; Gaulke and Horn, 2004; de Lisle, 2007
scalaris	Insects, other invertebrates, reptiles, birds	de Lisle, 1996; Bennett, 1998; Sweet, 2007
semiremex	Other invertebrates (mainly crustaceans), fish, frogs, insects, reptiles, mammals	Jackson, 2005
spenceri	Mammals, reptiles, insects	Bennett, 1998; Jackson and Lemm, 2009

Table 1. *Continued*

Varanus sp.	**Dietary Items**	**Reference**
spinulosus	Insect, other invertebrates, birds	Böhme and Ziegler, 2007; Dwyer, 2008
storri	Insects, reptiles, other invertebrates	Bennett, 1998
timorensis	Reptiles, insects, other invertebrates	Bennett, 1998
tristis	Reptiles, insects (mainly grasshoppers), reptile eggs, birds, bird eggs, other invertebrates, leaves	Bennett, 1998; Pianka, 1971, 1982, 1994; Sweet, 2007
varius	Mammals, insects, other invertebrates, birds, reptiles, bird eggs, reptile eggs	Bennett, 1998; Guarino, 2001
yemenensis	Insects, other invertebrates	Bennett, 1998

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A Third Captive Generation of Komodo Dragons (*Varanus komodoensis*) at Rotterdam Zoo, The Netherlands

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Abstract - At Rotterdam Zoo, *Varanus komodoensis* has been bred to the third generation. Four offspring hatched in the enclosure of the parents. Total length and weights of the hatchlings are tabulated. A short discussion on imbreeding of this species in zoos is presented.

Introduction

In 1992, the first hatching of the Komodo dragon, *Varanus komodoensis*, outside of Indonesia occurred at the Smithsonian National Zoological Park in Washington D.C., USA, where 13 young dragons were born from wild-caught parents (Walsh et al., 1993). In 1995, in a great gesture of international cooperation, the management of the zoo in Washington D.C. sent several of these overseas to Komodo dragon keeping institutions, among them the zoos of Berlin and Rotterdam. Together with the few *V. komodoensis* that were already in European zoos, this became the nucleus of a new population.

Breeding Program

After an international zoo meeting in 1998 at the Zoo of Thoiry in France, it was decided to start a European Studbook for the *V. komodoensis* in the European zoo community, under the umbrella of the European Association of Zoos and Aquariums (EAZA). An international studbook as well as an American studbook, were already in place at the time. Two years later this European Studbook evolved into a so called “EAZA EEP”, a standardized breeding program for endangered species.

The program was and still is, coordinated by the Rotterdam Zoological and Botanical Gardens (Rotterdam Zoo, The Netherlands). The senior author of this paper became the species coordinator for Europe. In 2000, the population consisted of 17 animals in eight institutions (Visser and Belterman, 2000).

The First European Births

In 1999, Rotterdam Zoo was one of the zoos to receive three (1.2) young dragons from Washington. Four years later, it was decided to send one of those females to Reptilandia reptile park on Gran Canaria, Canary Islands, Spain for reasons of available space and most of all, for the climatic benefits; on the Canary Islands, *V. komodoensis* can remain outside under almost natural conditions for most of the year.

In 2001, Reptilandia managed to obtain a pair of captive born, F1 *V. komodoensis* from Gembira Loka Zoo, Yogyakarta, Indonesia, and so an unrelated potential F1 breeding pair was established. This resulted in a clutch of 32 eggs in February 2004 and, in September of the same year, the first hatching of F2 *V. komodoensis* in Europe, and within the EEP. A total of 17 young hatched successfully (Pether and Visser, 2007).

Further Births in Europe

Following Reptilandia's breeding, several births occurred in Europe. At the Zoological Society of London's London Zoo in Great Britain, one sexually-conceived F2 hatchling was born in August 2006. However, the event that had rocked the international reptile community prior to this hatching, was the birth of 4 parthenogenetic dragons in March 2006 (Watts et al., 2006; Sunter, 2008). In 2007, a further eight parthenogenetic *V. komodoensis* hatched at Chester Zoo (Great Britain).

Meanwhile, Prague Zoo (Czech Republic) had received an adult F1 pair from Indonesia (born in Taman Safari, Indonesia), which later produced three hatchlings in April 2007 (Velensky, 2007).

The Rotterdam Situation

In order to get the best possible results, animals within the EEP are placed in the most potentially favorable circumstances, which implies that in several cases adult *V. komodoensis* were moved around to different European zoos and replaced by subadults or even hatchlings that were born elsewhere within the EEP. This is done to make up for the "loss" of a nice adult specimen and with it the attraction value such an animal has for the public of the zoo in question. In that respect, the cooperation between zoos in this EEP is exemplary.

For Rotterdam, it meant that we had to send our large, and then solitary male to Great Britain, to be paired up with females at Chester Zoo. In return, Rotterdam Zoo received a young sibling pair from Gran Canaria (born September 2004) for exhibition purposes.

In July 2008, matings were seen, but since it is generally accepted that *V. komodoensis* reach sexual maturity at five or six years of age, these events were regarded as a form of "play" behavior, and no results were expected. The female was 3.5 years of age at the time. As it is rather easy to over-feed these animals, they were kept on a strict diet and therefore the animals grow

Fig. 1. The sibling pair of *V. komodensis* on exhibit at Rotterdam Zoo just after their arrival in 2007. Photograph by **Gerard Visser / Archives Zoo Rotterdam**

slowly. Hence, the pair is small compared to what was customary in the past. This rather smallish female indeed showed no signs of being gravid at all.

F3 Generation

We were of course greatly surprised to first find two, and then another young *V. komodoensis* in the 120m², fully-planted Komodo dragon exhibit on 10 and 11 March 2009. As we had noticed the "copulations" in July, the eggs may have been laid in August 2008. When we found the young dragons, the yolk sack had been fully absorbed, so we believe the young may have been a day or two old. The eggs had been buried in the exhibit's substrate, which was comprised of hard, loamy soil approximately one meter deep., in which the parents have dug several burrows and tunnels. Thus, in this soil, the eggs must have been incubating for ca. eight months.

After the young were found, we searched for the nest, further eggs, or egg shells, but nothing was found. To find the nest would have meant a total demolishing of the entire exhibit, which was, and still is not feasible.

Two months later, on May 10, we found another hatchling, adding up to a total of four youngsters. This is an indication of a prolonged hatching process. Since these hatchlings were born to an F2 sibling pair, they represent the first captive F3 generation of *V. komdoensis* ever produced.

The measurements and weights of these hatchlings (Table 1.) fall into the low end of the range of weights and lengths known from other captive born hatchlings that were artificially incubated. The animals show no birth defects. Additionally, the estimated incubation period seems to be rather normal. This would imply that the conditions in the soil of the exhibit were well suited for the incubation of monitor eggs, even during the rather cold winter of 2008-2009 when the ambient

Fig. 2. An F3 hatchling, two weeks after birth, feeding on a locust.
Photograph by **Marten van Dijl / Archives Zoo Rotterdam**

temperatures dropped to as low as 25ºC on cold days.

Inbreeding Allowed?

Although captive breedings involving sibling pairs is not recommended within the EEP-breeding programs, these animals can still play a significant role in the population. They may serve as "exhibit only" animals for zoos that just wish to keep *V. komodoensis* without further breeding goals, or as replacement animals for adults sent out to be grouped with others to form breeding pairs, and, in case of an emergency, they could still be used for breeding purposes in the future. The aim of the EEP is to keep genetic variability at a maximum level, so hopefully inbreeding will be a last resort. Our goal remains that the European *V. komodoensis* population will develop without further inbreeding. For that purpose, the EEP has sought and found cooperation with the zoos of Pretoria (South Africa) and Singapore. At the moment, several pairs are in position to breed and three institutions have received eggs in 2009. At the moment there are 19 participating zoos (in comparison to 8 in 2000), with a few more on the waiting list. The number of *V. komodoensis* in European collections has risen to 42 specimens, from just 17 in 2000. Hence, the future of the European *V. komodoensis* population may not be as gloomy as it seemed to be just a few years ago.

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Appendix

Table 1. Hatchling morphometrics.

No.	Snout-vent Length (cm)	Total Length (cm)	Weight (g)
1	17.5	41.1	85
2	18.0	40.3	85
3	17.5	42.5	90
4	14.5	39.0	70

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Cannibalism in Captive *Varanus timorensis*

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Abstract - An observation of cannibalism among sibling *Varanus timorensis* in captivity is presented. It is suggested that cannibalism may not be common in *V. timorensis*, however care should be taken when housing animals together.

An adult pair of wild-caught *Varanus timorensis* has been kept in captivity since 2004 in the author's private collection. On 5 February 2008, the female laid 13 eggs (8 fertile and 5 infertile). The eggs were placed into an aquarium-type incubator with an incubation substrate consisting of a perlite and water mixture (1:1 ratio by weight). The eggs were incubated at 29 °C, and began to hatch on 1 June 2008, after 117 days. Small slits were made on the eggs that hadn't pipped by themselves; one neonate was found dead in the egg. By the next day, all remaining hatchlings emerged, four healthy monitors and three with congenital spine deformities. The healthy hatchlings averaged 6.5 cm in snout to vent length (SVL) and 16 cm in total length (TL), and 4 g.

The seven hatchlings were placed together in a glass enclosure measuring 50 x 30 x 35 cm (l x w x h). The enclosure consisted of newspaper substrate, cork bark-covered enclosure walls, numerous branches and a shallow water dish (2 cm deep). The ambient room temperature was maintained at 27 ºC and a 26 W Exo-terra ReptiGlo 5.0 light bulb was placed on the top of the enclosure for additional basking and UVB exposure. Two out of the three deformed monitors died within 2 days of hatching, both found dead in the water dish. The remaining one started to eat, along with the healthy ones, on wild-caught insects dusted with Korvimin ZVT+Reptil vitamin and mineral supplement. Food was offered on a daily basis. Despite some difficulties in moving, the deformed juvenile gained weight. Minor fights among the young monitors were observed during feeding time when the same prey item was captured by more than one individual. The fights mainly targeted

Fig. 1. Hatchling *Varanus timorensis* emerging from eggs.

Fig. 2. A one week old juvenile *V. timorensis*.

Fig. 3. Neonate with noticeable spinal deformity at the base of the tail.

the deformed individual where it was often grabbed by a stronger sibling. Since these fights had no serious consequences, the author decided to leave them together in the group.

On 10 August 2008, the author left the juveniles alone after offering them wild-caught insects. Returning twenty minutes later, he found one healthy juvenile attempting to swallow the deformed sibling. At the time of observation, the head had already been fully swallowed. The forelegs and part of the abdomen was inside the mouth of the healthy one. The deformed juvenile remained motionless and appeared dead. The consumer had difficulties swallowing and moving with the sibling, and attempts were made to remove the deformed individual from the throat as it could have led to the death of both animals. By the time the deformed monitor was retrieved, it was already dead. The healthy juvenile immediately scurried away without any problems. Within one minute, it started to eat an appropriate sized grasshopper. At the time of observation, the two juveniles were of equal size (mass, SVL and TL). The remaining siblings were left together in the same cage without further problems.

Cannibalism has been documented in other species of monitors including *V. salvator* (Shine et al., 1996), *V. rosenbergi* (King and King, 2004) and *V. griseus* (Stanner, 2004). Based on the literature, cannibalism has not been documented in *V. timorensis* (Schmutz and Horn, 1986; King and Smith, 2004) and even small groups can be kept together (Behrmann, 1981; Lambertz, 1995; Bennett, 1998). The cause of cannibalism in this case remains unknown. The author suspects two possibilities for this unusual behavior. The first possibility is that the two animals started to eat the same prey item and the stronger individual held on and began to swallow the weaker one. The other possibility is that the abnormal movements of the deformed monitor resembled a prey item. In the wild, *V. timorensis* occasionally consume smaller reptiles (Losos and Greene, 1988; King, 1993). This, combined with the feeding time and the scent of insects in the cage, could have triggered predation on a conspecific. The author doesn't state that cannibalism is common in *V. timorensis*, but care should be taken when placing healthy animals together with unhealthy ones.

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Australia has long been famed for its unusual and unique wildlife, particularly its reptiles and amphibians. In turn, this has generated global demand for its herpetofauna among zoos and private collectors. Although there have been many popular and technical articles written on the herpetoculture of Australian species, there are few books which truly provide detailed and comprehensive accounts capable of advancing herpetocultural knowledge and practice (e.g., Swan, 2007; Hitz et al., 2004; Hausschild and Bosch, 2000; Vincent and Wilson, 2000). Sadly, the majority of books written to date on the husbandry and captive reproduction of Australian lizards have been limited to dumbed-down, pet shop books intended for a beginner audience (e.g., Goulding and Green, 2007; Purser, 2006; Raffery, 2003; de Vosjoli and Mailoux, 2001; Turner, 2001; Green, 2001; Green and Larson, 2001; Walls, 1996). Given this void in the herpetocultural literature, books which discuss the care and breeding of Australian lizards in detail and promote innovative approaches to herpetoculture are much needed among both amateur and professional herpetoculturists.

Keeping and Breeding Australian Lizards is the latest herpetocultural title published by Mike Swan Herp Books, presenting an array of current and up to date information on the husbandry and breeding of Australian lizard taxa presently maintained in Australian collections. The book is organized in a similar fashion to the publisher's earlier title, *Keeping and Breeding Australian Pythons* (2007), with several authors contributing sections based on their areas of expertise or taxonomic specialization. The book features over 1,000 color photographs and is divided into several main sections.

The book begins with a brief overview of lizards, discussing lizard diversity, morphology, physiology and ecology, followed by an introduction to the lizard diversity of Australia. The subsequent chapter provides a general overview of lizard husbandry, discussing specimen selection, housing ratios, handling, enclosure design and construction, substrates and enclosure furnishings, heating and temperatures, lighting, feeding, water, sloughing, and record keeping. The following chapter on lizard breeding includes brief discussions of sex determination, reproductive phenology, winter cooling, mating, egg development, oviposition, incubation, and the care of lizard offspring. These sections are generalized in their scope of coverage, and leave remarks on specific taxa for the species accounts appearing later in the book.

The following section by Rob Porter covers the rearing of insects for food. Here, the author discusses techniques used to culture a variety of insects including domestic crickets (*Acheta domesticus*), wood cockroaches (*Nauphoeta cinerea*), mealworms (*Tenebrio molitor*), giant mealworms (*Zoophoba morio*), wax moth larvae (*Galleria mellonella*), silkworms (*Bombyx mori*), and migratory locusts (*Locusta migratoria*). Also discussed is the practice of dusting prey items with vitamin and mineral supplementation. Next, is a chapter on the diseases and disorders of Australian lizards by Fransiscus Scheelings. This chapter is divided into several smaller sections, covering nutritional disorders, metabolic bone disease, periodontal disease, reproductive disorders, parasitism, trauma and dysecdysis. Also included are important considerations for quarantining new animals, and a useful formulary of anesthetics, analgesics, antibiotics, and antiparasitic drugs. The section is well-referenced, with literature citations appearing at the end of the chapter.

Making up the bulk of the book's 613 pages are the species accounts. These accounts are arranged taxonomically, with five main sections based on the major Australian lizard groups: the gekkonids, pygopodids, scincids, agamids and varanids. Each section begins with an introductory chapter on the taxonomy and natural history of the group, with color photographs depicting representative species, as well as general information regarding captive management such as housing, diets, temperature and environmental conditions, breeding, egg incubation, and quarantine of new specimens. Individual chapters within each major section are arranged according to genera, individual species, closely-related taxonomic groups (e.g., "mulga monitors"), or ecologically-defined groups (e.g., "water monitors"). Each chapter begins with an overview of the natural history of the species, genus or group, with corresponding distribution maps and color photographs for all Australian representatives and their corresponding habitats. Detailed accounts on captive husbandry, breeding, incubation and rearing of offspring follow, with color photographs depicting captive specimens, enclosures, courtship behavior, eggs, and captive bred offspring, concluding with accompanying tables presenting useful breeding data for each species such as egg and hatchling morphometrics, gestation and incubation periods, and incubation temperatures. Although not exhaustive, all chapters are well-referenced, with citations appearing at the end of each chapter.

Following the species accounts is a final chapter on color and pattern aberrations, discussing the various Australian lizard species which have been line-bred for specific color and pattern mutations in captivity, descriptions of several common mutations, and a brief overview of mendelian genetics and its applicability to reproducing these traits in captivity. Completing the book is a brief glossary of terms followed by an index searchable by species.

Since this review is appearing in a specialized varanid publication, it is important for me to discuss the *Varanus*-related material contained within this book. Authored by Australian varanid herpetoculturists Grant Husband and Matthew Bonnett, the 100 page section devoted to monitor lizards is divided up into eight individual chapters: spiny-tailed monitors (*V. acanthurus, V. baritji, V. primordius* and *V. storri*), pygmy desert monitors (*V. brevicauda* and *V. eremius*), terrestrial monitors (*V. giganteus, V. gouldii, V. panoptes, V. rosenbergi* and *V. spenceri*), mulga monitors (*V. bushi*, *V. gilleni*, *V. caudolineatus*), rock monitors (*V. glauerti, V. glebopalma, V. kingorum* and *V. pilbarensis*), tree monitors (*V. kiethhornei*, *V. prasinus, V. scalaris* and *V. tristis*), water monitors (*V. mertensi*, *V. indicus*, *V. semiremex*, *V. mitchelli*), and lace monitors (*V. varius*). The general overview of the genus in the introductory chapter is brief and concise, covering an assortment of topics pertaining to natural history, ecology, morphology and reproduction.

The authors provide detailed husbandry information, data, and recommendations gathered from their own first-hand experiences, personal communications with other varanid herpetoculturists, and consultation of primary and secondary literature sources. In addition to providing useful breeding data for each species such as gestation and incubation periods, and incubation temperatures, the authors address several important topics which have been viewed among varanid herpetocultural circles as controversial. For example, the practice of housing monitors in enclosures with 24 hour exposure to lighting and heat, as promoted by some North American varanid keepers, is strongly contested and argued against, reminding readers that a normal photoperiod as would be experienced in the wild, has its health advantages and reduces the risk of animals "burning out" in captivity. Another topic which is thoroughly discussed throughout the book is the importance of vitamin and mineral supplementation and exposure to ultraviolet light, particularly for specimens maintained indoors without access to natural sunlight.

Focusing the majority of my attention on the introductory chapters and the varanid species accounts, I have very few criticisms of this book; all of which I consider to be minor and shouldn't affect its overall resourcefulness and value to the reader. Perhaps my biggest criticism is the way in which the authors grouped several non-related varanid species together into ecologically-defined groupings such as "water monitors" and "tree monitors". Species grouped together within these two particular categories belong to different subgenera and differ substantially in both their ecologies and captive husbandry. For example, under the category "tree monitors", the authors chose to group two members of the subgenus *Odatria*, *V. tristis*, an inhabitant of woodlands, sub-humid tropical woodlands, and rocky ranges and outcrops across most of Australia (Pianka, 2004), and *V. scalaris*, an inhabitant of savannah woodlands across northern Australia (Smith et al., 2004), together with *V. prasinus* and *V. keithhornei*, both members of the subgenus *Euprepiosaurus* and inhabitants of humid monsoon, rain and palm forests, mangrove swamps and cocoa plantations (Greene, 2004) in New Guinea and far north Queensland, Australia. Aside from their taxonomic, biogeographic and ecological differences, they also vary considerably in their care and upkeep in captivity (pers. obs.), having different thermal and hydric demands, and requiring different humidity levels, cage furnishings, and refuge sites. The same can be said about *V. indicus* grouped together with *V. mertensi*, *V. mitchelli* and *V. semiremex* as "water monitors". I feel that it would have been more appropriate to assign these species (*V. prasinus* and *V. keithhornei*; and *V. indicus* respectively) their own groupings and corresponding chapters.

To date, I have yet to encounter any book which organizes its varanid species accounts based on phylogenetic relationships (for current varanid phylogenies, see Ast, 2001; Fitch et al., 2006; Ziegler et al., 2007) rather than the typical alphabetized species listings seen in previous titles (e.g., Pianka and King, 2004; Bennett, 1998; De Lisle, 1996; Eidenmueller, 2007). As far as could be determined, this book represents the only current title which groups varanid species accounts along the lines of phylogenetic relationships. By grouping related species together, this allows for interspecific comparisons in which the information presented for one species may also be applicable to similar species. For this, I commend the authors, and hope that future titles written on *Varanus* are organized in a similar fashion.

The only other notable criticism I have of this book is the quality of the color photographs. The book itself is chock-full of more than 1,000 color photographs, however their colors appear to be faded and inaccurate, exhibiting a washed-out or sepia-like tone. For example, when looking at images of lush Queensland rainforest, it is easy to see that the greens are quite faded and not representative of the natural coloration of the foliage. Likewise, the colors of lizard taxa depicted in this book may not be accurate represenations of their actual coloration. In speaking with other owners of the book, these color issues appear to be consistent in all first-run copies, and are not limited just to my book. This of course is not a major issue, for I assume this can easily be resolved in future printings of the book.

Minor criticisms aside, I feel that this book presents the most comprehensive and up to date compilation of information available on varanid husbandry and breeding. The written and photographic documentation in this book are superb and second to none. Having been written by knowledgeable and experienced herpetoculturists with repeated success in the captive breeding of several species of monitor lizard, this book offers information and advice that will undoubtedly improve readers' understanding of the demands and requirements of monitor lizards in captivity, and help advance the hobby. While the book pertains exclusively to Australian taxa, much of the information presented on monitor lizards may also be applicable to the husbandry and breeding of non-Australian varanid species.

Although this review is heavily *Varanus*-oriented, it is important for me to point out that the section on monitor lizard*s* makes up only about 20% of the book's species accounts, and that there is also a myriad of detailed accounts on gekkonids (by John McGrath), pygopodids (by Rob Porter), scincids (by Greg Fyfe) and agamids (by Kieran Aland). Although my lack of familiarity with the herpetoculture and natural history of many of these species prevents me from being able to adequately critique or review these sections, it appears that the same level of care and attention was put into their preparation as the section on *Varanus*, with each chapter presenting detailed information and breeding data, with pertinent literature citations, and plenty of color photographs. Therefore, there is no reason for me to believe that these sections would be any less valuable to the herpetoculturist than other sections of the book. The information and photographs packed within the 140 page gekkonid, 42 page pygopodid, 129 page scincid, and 93 page agamid sections, will undoubtedly make this book a significant contribution to the herpetoculture of any of these major lizard groups.

In conclusion, Swan and the sectional authors have done a superb job of setting the bar for what herpetocultural books should look like and present, rather than the watered-down regurgitations that many good-intentioned herpetocultural books often become. Whether you're a private keeper, breeder, zoo keeper or herpetological enthusiast, this book will make an invaluable addition to the personal library.

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CURRENT RESEARCH

New Monitor Species from Indonesia

In the new issue of *Australian Journal of Zoology*, André Koch from the Zoologisches Forschungsmuseum A. Koenig Bonn (ZFMK), Germany, and colleagues describe a new monitor species from Indonesia. *Varanus lirungensis* is known only from the small Talaud island group located in the triangle between northern Sulawesi, Mindanao (Philippines) and Halmahera (Moluccas). The species name refers to the type locality near the village of Lirung on Salibabu Island (Fig. 1).

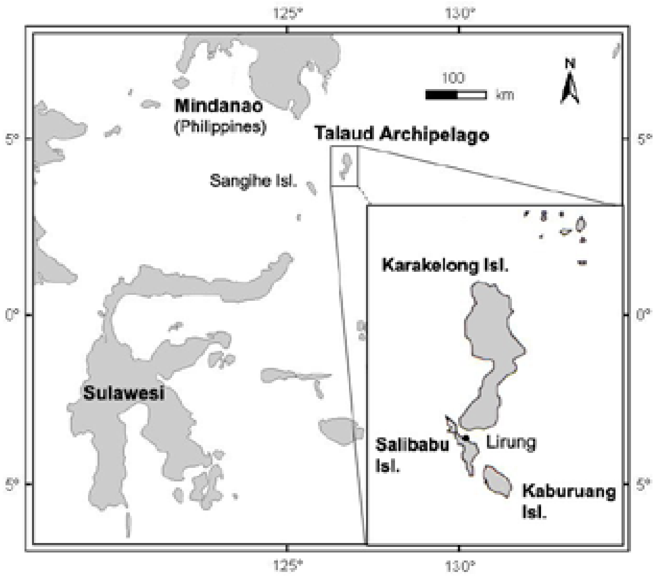

Fig. 1. Distribution of *Varanus lirungensis*

Besides molecular evidence, *V. lirungensis* is characterized/distinguished by a vivid dorsal colour pattern of yellow markings and faded dark crossbands on the ventral side (Fig. 2); a pinkish throat; hemipenis with paryphasman rows on both sides of the sulcus; and high scale counts around midbody, neck, and base of tail.

The new cryptic species represents the most north-western occurrence of a member of the Mangrove monitor species group around *V. indicus*.

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Fig. 2. The male holotype of *V. lirungensis* from Salibabu Island, Talaud Archipelago. Photograph by **André Koch**.

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