

First Captive Breeding of the Blue Tree Monitor *Varanus macraei* Böhme & Jacobs, 2001 at the Plzen and Cologne Zoos

THOMAS ZIEGLER^{1,*}, MELANIE STRAUCH¹, TOMAS PES²,
JAN KONAS², TOMAS JIRASEK², NORBERT RÜTZ¹,
JOHANNES OBERREUTER¹ and SIMONE HOLST¹

¹Cologne Zoo
Riehler Straße 173
D-50735 Köln, Germany

²Zoologicka a botanicka zahrada mesta Plzne,
Pod Vinicemi 9
30116 Plzen, Czech Republic

*Corresponding author
E-Mail: ziegler@koelnerzoo.de

Abstract - The blue tree monitor, *Varanus macraei*, was described in 2001 from Batanta Island off Irian Jaya, Indonesian New Guinea. Only scarce information is available on its natural history, and breeding reports thus far have only been published from private holdings. The first successful breedings from within zoological gardens, at the Plzen and Cologne Zoos, are herein reported. Altogether, 37 eggs were laid and 24 juveniles have hatched to date. Furthermore, this data are compared with previously published information on the successful breeding of the species, and for the first time, proof of an individual recognition system for *V. macraei* based on neck patterns is provided.

Introduction

Varanus macraei was only recently described by Böhme and Jacobs (2001) and is known only from Batanta Island, northwest of the Vogelkop Peninsula of Irian Jaya, Indonesian New Guinea. The species belongs to the emerald tree monitor (*V. prasinus*) group, which is currently comprised of nine species: *V. prasinus*, *V. beccarii*, *V. kordensis*, *V. bogerti*, *V. keithhornei*, *V. telenesetes*, *V. macraei*, *V. boehmei* and *V. reisingeri* (Ziegler et al., 2007). *Varanus macraei* is a large, slender tree monitor with smooth, unkeeled nuchal scales and a unique dorsal color pattern consisting of numerous oblique, irregular rows of blue ocelli on a black ground

color. Maximum size is 110 cm in total length, with a maximum snout vent length (SVL) of 36 cm in males and 31.3 cm in females (Böhme & Jacobs, 2004). *Varanus macraei* is a diurnal, highly specialized tree monitor, as are the other members of the *V. prasinus* group. Because the size of Batanta Island is only 455 km², with a maximum length of 61 km and a maximum width of 13 km, *V. macraei* has one of the smallest distributions among *Varanus*, and virtually nothing is known about its habitat and natural history (Böhme & Jacobs, 2001; 2004). The first breeding of *V. macraei* in captivity was published by Jacobs (2002). Further breeding successes in private

facilities were subsequently published by Dedlmar (2007) and Moldovan (2008). Moreover, Mendyk (2007) reported on dizygotic twinning in *V. macraei* and Dedlmar (2008) on a two-headed hatchling. However, to our knowledge, there have been no documented zoo breedings of this rare and certainly endangered species. Thus, the first successful zoo breedings of *V. macraei*, at the Plzen and Cologne Zoos are herein reported.

Breeding Pairs

On 21 January 2004, the Plzen Zoo received a subadult pair of *V. macraei*, which was sent from Jakarta and subsequently confiscated at Prague airport. In April 2009, the female specimen measured 300 mm SVL and 620 mm tail length (TL) (920 mm in total length), the male measured 330 mm SVL and 660 mm TL (990 mm in total length). Three years later, in January 2007, Cologne Zoo received a confiscated pair of adult *V. macraei* from the Wildtier- und Artenschutzstation e.V. Sachsenhagen in Germany. On 28 April 2009, the female specimen (Fig. 1) measured 275 mm SVL and 575 mm TL (850 mm in total length), the male measured 290 mm SVL and 640 mm TL (930 mm in total length).

Both wild-caught pairs made up the unrelated breeding stocks of the Plzen and Cologne Zoos. Both

breeding pairs from Plzen and Cologne are undoubtedly members of the *V. prasinus* group and assignable to the species *macraei* due to their prehensile tails which are roundish in cross section, in combination with unkeeled, smooth neck scales, dorsal patterns consisting of transversal rows of blue ocelli, and tails bearing alternating blue and black bands (Ziegler et al., 2007).

Housing

Cologne Zoo

The confiscated pair of *V. macraei* was placed together in a glass terrarium measuring 200 x 100 x 70 cm (L x W x H). The breeding pair was kept behind the scenes, inaccessible to the public. The enclosure was equipped with massive branches, cork tubes, and live plants (e.g., *Ficus* sp.) for climbing and hiding. The substrate consisted of pine bark. Light was provided by two fluorescent tubes (54 W) and two basking lamps (100 W) which also supplied ultraviolet light. Photoperiod was approximately 13:11 h (light:dark), however some lights were regularly turned off to simulate natural cloud cover, controlled by timers. Ambient temperatures of 29–32 °C were provided by light sources with a maximum temperature up to 40 °C directly beneath the basking



Fig. 1. The confiscated wild-caught female *Varanus macraei* after one year at Cologne Zoo (12 Jan. 2008). Photograph by **Thomas Ziegler**

lamps. A wooden nesting box was located in one corner of the enclosure and a clay nesting box was located in the middle of the rear of wall of the enclosure. The nesting boxes were accessible by a small hole and were filled with humid sphagnum moss, sand, and leaf litter at a ratio of 1:1:1, providing a beneficial microclimate due to the emerging compost heat. The enclosure further provided a water basin measuring 64 x 68 x 11 cm (L x W x H). Ambient humidity was around 70 % due to the water basin and daily misting.

The pair was predominantly fed live insects such as locusts, dusted with calcium (CALC Mineral) and/or vitamin powder (Korvimin ZVT) up to five times a week. Dead baby mice were offered supplementally, as well as chopped-up day-old chicken and fish occasionally.

The monitors were relatively shy and often disappeared when approached. Because of the particularly nervous behavior of the male early on in its captivity, it often collided with the glass panes of the enclosure and resulted in snout injuries and subsequent deformations.

Plzen Zoo

The breeding pair was housed in a terrarium measuring 100 x 100 x 150 cm (L x W x H). The side and rear walls were constructed with wooden panels (OSB) and the front consisted of a glass door. Three round ventilation holes (10 cm in diameter) covered by wire mesh were situated under the door and an additional ventilation hole measuring 10 x 100 cm was located on the rear wall 20 cm down from the ceiling. The terrarium was equipped with plastic plants, two wooden shelves, and some branches. The walls and furniture could be used for climbing, allowing the entire space of the terrarium to be utilized. Wood chips were used as substrate. Light and heat was provided by a white fluorescent tube (18 W) measuring 60 cm in length, a Sera UV 5 light tube (18 W) and a T-Rex Active UV Heat (100 W), controlled by a thermostat and switched off at temperatures above 30°C. A water dish measuring 50 x 25 x 20 cm was used for water supply. Additionally, the terrarium was sprayed with water twice a day (in the morning and in the afternoon); thus ambient humidity ranged between 70 and 90%. A wooden box with one side made of glass was used for egg-laying. It measured 25 x 25 x 30 cm and was filled with a 5-6 cm deep layer of peat. The box provided an entrance hole (6 cm in diameter) situated 3 cm from the top and was mounted on the upper third of the enclosure's rear wall.

Animals were fed crickets twice a week and mice

twice a week. Occasionally, mice were replaced by 5-6 locusts. Vitamins were initially supplemented with NUTRIMIX for poultry and eventually replaced by PLASTIN with Amino Rep F.

Mating and Gestation Period

Cologne Zoo

As an indication of the mating season (e.g., the female's receptivity) the female was observed approaching the male. During this time, the pair was often seen resting close to each other. Copulations were observed several times before deposition of the clutches. The time between observed copulations and egg depositions ranged from 25 to 35 days. Vertical copulatory positions as reported by Moldovan (2008) and photographed by Dedlmar (2007) could not be observed. Copulations always took place in a horizontal position on the cork tube; however, this may be reliant on the structure and general shape of the terrarium. Observed copulations lasted at least 5-6 min.

Concordant with Dedlmar's (2007) statements, the female was observed frequenting basking sites with UV lights during gestation. During this time, the female was also restless and almost always in motion, which may be due to the increasing food demand. However, a few days before oviposition, the gravid female refused food. Digging or other physical cues indicating gestation or forthcoming oviposition, such as the swelling of the abdomen, were not observed.

Plzen Zoo

After observing initial copulation attempts, keepers always limited their visits to the animals. Consequently, copulation was never observed. Approximately three weeks after perceived copulation attempts, the male was always separated from the female because of increasing aggression by the female. Two weeks after egg deposition, the female became less aggressive and the male was returned to the enclosure.

Egg Deposition and Incubation

Cologne Zoo

Egg deposition by *V. macraei* occurred three times at Cologne Zoo. Six months after their confiscation, on 17 June 2007, the adult pair laid eggs for the first time, approximately four to five weeks after observed mating

behavior. In total, four eggs were laid in the wooden nesting box. Eggs were not buried, but deposited on top of the nesting substrate. For incubation, eggs were removed and carefully placed in plastic boxes which were half-filled with vermiculite and sand at a ratio of 2:1 as incubation substrate. Eggs were not turned, and were placed on the surface of the vermiculite. The plastic boxes measured 20-22.5 x 12-14 x 14 cm (L x W x H) and contained two eggs each. For incubation, the plastic boxes were placed inside a large medicinal incubator.

The first clutch was incubated at a temperature of 29.3°C with a substrate humidity of 97 % (Table 1). From the four eggs, four juveniles hatched after 154-158 (156±1.8) days of incubation between 17 and 21 November 2007. Several days before hatching, the egg shells showed a red marbling and denting, which disappeared shortly before the hatching process. Because one egg (egg no. 3 in Table 1) developed further dentations and a stronger red marbling than observed in both previously hatched eggs, it was decided to manually open it to ease the hatching process. Because the juvenile was in good condition, the fourth egg was not opened and hatched one day later on 21 November. Egg shells measured 42-50 x 23-25 mm after hatching. The hatching process began with longish slits made at the head end of the egg. The snout of the hatching juvenile protruded for some hours and hatching was usually completed within 24 h (Figs. 2-4).

Nearly eight months after deposition of the first clutch, the same pair laid eggs again on 5 February 2008. Four eggs were immediately found, and remains of a fifth egg were found in faeces in the enclosure several days later. Although egg deposition and incubation did not change, three of the four incubated eggs were disposed of after 2-3 weeks because they did not show signs of development and began to decay. The remaining egg hatched on 13 July 2008 after 160 days of incubation.

A third clutch was laid by the confiscated wild-caught female in March 2009, but this time the father was an approximately two year old male offspring of the wild-caught breeding pair at the Plzen Zoo. This far-calm male replaced the aforementioned wild caught male at Cologne Zoo in February 2009. Three eggs were laid on 20 March 2009, approximately 39 days after the pair was introduced and 25 days after copulation had been observed. Two eggs measuring 45-46 x 18-19 mm were found in a cork tube that provided relatively humid conditions due to increased misting at that time. The third egg must have been eaten again by one of the parents, because the shell was found in faeces inside the terrarium. The remaining two eggs did not show signs of development and began to decay.

Plzen Zoo

At the Plzen Zoo, six clutches of *V. macraei* eggs

Table 1. Egg incubation for *V. macraei* at Cologne Zoo. Egg shells were measured after hatching; * artificial hatching (egg was opened); ** measured 5 days after egg deposition.

N°	Egg Deposition (date)	Clutch Size (eggs)	Egg Shell Size (mm)	Incubation Temperature °C	Substrate Humidity	Hatching (date)	Incubation Period
1	17 Jun 07	4	49 x 23	29.3	97%	17 Nov 07	154
2	17 Jun 07	4	50 x 23	29.3	97%	18 Nov 07	155
3	17 Jun 07	4	42 x 25	29.3	97%	20 Nov 07*	157
4	17 Jun 07	4	48 x 25	29.3	97%	21 Nov 07	158
5	5 Feb 08	5	48-50 x 19-21	29.3	97%	13 Jul 08	160
6	5 Feb 08	5	48-50 x 19-21	29.3	97%	Dead	-
7	5 Feb 08	5	48-50 x 19-21	29.3	97%	Dead	-
8	5 Feb 08	5	48-50 x 19-21	29.3	97%	Dead	-
9	20 Mar 09	3	46 x 18**	29.3	97%	Dead	-
10	20 Mar 09	3	45 x 19**	29.3	97%	Dead	-



Fig. 2. At early hatching stage, only the snout of the juvenile *V. macraei* is protruding (16 Nov. 2007). Photograph by **Thomas Ziegler**



Fig. 3. Hatching *V. macraei* (16 Nov. 2007). Photograph by **Thomas Ziegler**



Fig. 4. The juvenile *V. macraei* depicted in Figs. 2-3 upon hatching (17 Nov. 2007); the prehensile tail of the first hatchling in the Cologne Zoo is already well discernible. Photograph by **Thomas Ziegler**

have been laid within a two year period. The eggs of the first clutch laid on 15 June 2006 were measured and their sizes ranged between 50-55 mm (52.5 ± 2.4) in length and 14-18 g (15.3 ± 1.9) in weight.

All eggs laid up until now have been incubated in plastic boxes filled with moist vermiculite in a Jäger FB 80 incubator. Incubation temperatures ranging from below 28 °C to 31 °C were tested with different clutches and failed to demonstrate any correlation between temperature and sex of hatchlings (for details see Table 2). Both sexes hatched at low and high temperatures. At temperatures below 28 °C all embryos died. Because of these attempts, eggs are currently incubated at 29 °C.

Sexes of monitor lizards were determined through a combination of probing and palpation, and observation of noticeable sexual dimorphism (head size, tail base swelling). Sometimes, captured males spontaneously everted hemipenes which was used as evidence for male sex, and during some health assessments, radiography was used to check for genital mineralizations (visible in males due to mineralized hemibacula; not visible in females due to unmineralized hemibaubella; see, e.g., Ziegler and Böhme 1996, 1997). Males were usually recognized at a rate of 100%; sexing of females became reliable at an age of about one year (then, head shape and tail base swelling proved to be distinct indicators

of sex). Another indicator of sex was behavior, with females more submissive and nervous than males.

Development

Cologne Zoo

The four juveniles from the first clutch had SVL of ca. 90 mm, and TL of 130-140 mm. Their weights two days after hatching were 10-11 g. Since the artificially-hatched juvenile was weighed with its remaining egg yolk, its weight was 14 g. Hatchlings from the first clutch were housed together for approximately two months in a glass terrarium measuring 60 x 85 x 60 cm (L x W x H). They were subsequently moved to individual enclosures as a result of increasing differences in size. The juvenile from the second clutch was solely kept in an exhibit measuring 50 x 80 x 60 cm (L x W x H) since hatching. All enclosures provided conditions similar to the enclosure of the breeding pair. Hatchlings began feeding on small migratory locusts within a few days after hatching. Further hatchling husbandry took place without complications. However, it is interesting to note that the juveniles developed different food preferences, e.g., for mice or locusts. Of the four hatchlings from the first clutch of *V. macraei*, one was unfortunately stolen



Fig. 5. Two hatchlings from the first *V. macraei* clutch at Cologne Zoo (20 Nov. 2007). Photograph by **Norbert Rütz**

Table 2. Egg incubation for *V. macraei* and sexes of hatchlings at the Plzen Zoo.

N°	Egg Deposition (date)	Clutch Size (eggs)	Incubation Temperature °C	Hatching (date)	Incubation Period	Sex
1	15 Jun 06	4	30	15 Nov 06	153	-
2	15 Jun 06	4	30	18 Nov 06	156	1.0
3	2 Dec 06	4	31	1 May 07	150	0.1
4	2 Dec 06	4	31	3 May 07	152	1.0
5	2 Dec 06	4	31	5 May 07	154	1.0
6	2 Dec 06	4	31	5 May 07	154	-
7	1 Apr 07	4	29	30 Sept 07	183	0.1
8	1 Apr 07	4	29	29 Sept 07	182	-
9	1 Apr 07	4	28.5	11 Dec 07	194	0.1
10	1 Apr 07	4	28.5	16 Oct 07	199	-
11	29 Jul 07	4	29.5	12 Jan 08	167	0.1
12	29 Jul 07	4	29.5	20 Jan 08	175	1.0
13	1 Nov 07	5	29.5	10 Apr 08	162	0.1
14	1 Nov 07	5	29.5	11 Apr 08	163	0.1
15	1 Nov 07	5	28.5	18 Apr 08	170	1.0
16	1 Nov 07	5	28.5	19 Apr 08	171	1.0
17	22 May 08	4	29.5	10 Nov 08	173	-
18	22 May 08	4	29.5	14 Nov 08	177	-
19	22 May 08	4	29.5	15 Nov 08	178	-

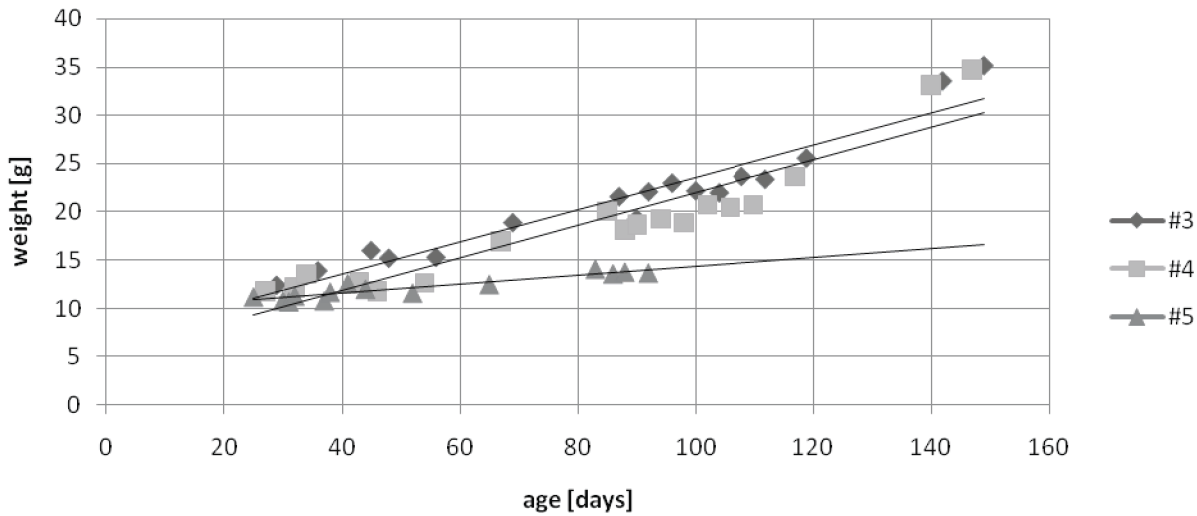


Fig. 6. Weight increases of *V. macraei* hatchlings during the first 5 months from the second clutch laid at the Plzen Zoo (eggs N° 3-5).

Table 3. Previously published data on the successful breeding of *V. macraei* in private facilities, after Jacobs (2002), Dedlmar (2007) and Moldovan (2008). Mean ± standard deviation are given in parentheses.

	Jacobs (2002)	Dedlmar (2007)	Moldovan (2008)
Number of Clutches	1	5	1
Number of Eggs (per clutch)	4	2-4 (2.8±0.8)	7
Number of Eggs (total)	4	14	7
Egg Size (mm)	43-45 x 20-21 (43.7±1.2 x 20.7±0.6)	47.1-52.5 x 20.3-22.3 (48.9±1.6 x 22.0±0.5)	-
Egg Weight (g)	9.0-10.0 (9.3±0.6)	-	-
Incubation Temperature °C	29.0-30.0	28.5	28.5
Incubation Period	159	206-240 (218.1±15.0)	169-177 (173.2±3.0)
Number of Hatchlings	2	7	5
Snout to Vent Length (mm)	95-100 (97.5±3.5)	-	88-91 (89.2±1.3)
Tail Length (mm)	140-150 (145.0±7.1)	-	125-130 (127,6±1,8)
Total Length (mm)	235-250 (242.5±10.6)	239-264 (250.0±10.0)	213-221 (216.8±3.0)
Weight (g)	12.0-13.0 (12.5±0.7)	11.9-14.3 (12.7±1.0)	11.0-12.0 (11.4±0.5)

(see below), one was exchanged with Plzen Zoo, and two remain at Cologne Zoo (Fig. 5). On 28 April 2009, they measured 230-240 mm SVL, 435-455 mm TL, 665-695 mm in total length and their weights were 170-180 g. The specimen exchanged with Plzen measured 240 mm SVL, 470 mm TL, 710 mm in total length, and weighed 151 g in May 2009.

Plzen Zoo

Juveniles primarily weighed between 13 and 15 g shortly after hatching. The two hatchlings of the first clutch which hatched on 15 and 18 November 2006 weighed 13 and 15 g respectively on 28 November. On 2 January 2007, their weight was 10 and 20 g. The declining weight of the first hatchling indicated its forthcoming death. The other juvenile was later transferred to Cologne Zoo. Weight increases of viable hatchlings from the second clutch (egg nos. 3-5) were measured during the first 5 months of life (Figure 6).

Hatchlings were kept in separate terrariums. Later, juveniles from the same clutch were placed together in groups. They were housed in glass terrariums measuring 125 x 80 x 55 cm (L x W x H). The terrariums were situated in a quiet location above the keepers' heads

because young hatchlings proved to be stress-sensitive. Stress might lead to food refusal and weight decrease below 9 g, which seems to be lethal.

Comparisons with Breeding Successes in Private Facilities

In captivity, clutches of *V. macraei* may range in size from 2-7 eggs with a mean of 3.9 ± 1.2 eggs per clutch (see Tables 1-3). Up to four clutches may be laid throughout the year (Mendyk, 2007). The shortest interval between subsequent clutches of the same breeding pair was 95 days, as was documented at the Plzen Zoo. However, most of the clutches (64.7%) were deposited during European winter time, from October to March. This may be due to the reduced amounts of rainfall experienced during this time of year in the natural habitat of *V. macraei*, as was documented by Moldovan (2008) for Sorong, Bird-head Peninsula. Copulations were observed from November until May, but most frequently from November until January. According to observations and data from the literature, the period between copulation and egg deposition takes about five to seven weeks. Egg size varied from 43 to 55 mm in length and 20 to 22.3 mm in width (Tables 1 and 3). In captivity, incubation

Table 4. Incubation period and hatchling size/weight of *V. macraei* in relation to incubation temperature. After own data (successful breeding at Cologne and Plzen Zoos) and data provided by Jacobs (2002), Dedlmar (2007) and Moldovan (2008); mean \pm standard deviation are given in parentheses; 1 one of five hatchlings was weighted with egg yolk; 2 measured 4-7 days after hatching; 3 measured 25-29 days after hatching.

Incubation Temperature °C	Number of Eggs	Incubation Period	SVL (mm)	TL (mm)	TTL (mm)	Weight (g)
28.5	16	169-240 (195.4 \pm 24.1)	88-91 (89.2 \pm 1.2)	125-130 (127.6 \pm 1.8)	213-264 (236.2 \pm 18.7)	11.0-14.3 (12.2 \pm 1.1)
29	2	182-183 (182.5 \pm 0.7)	-	-	-	-
29.3	5	154-158 (156.8 \pm 2.4)	90	130-140 (135.5 \pm 7.1)	220-230 (225.5 \pm 7.1)	10.0-14.0 (11.25 \pm 1.9) ¹
29.5	7	162-178 (170.7 \pm 6.7)	-	-	-	-
29-30	2	159	95-100 (97.5 \pm 3.5)	140-150 (145 \pm 7.1)	235-250 (242.5 \pm 10.6)	12.0-13.0 (12.5 \pm 0.7)
30	2	153-156 (154.5 \pm 2.1)	-	-	-	13.0-15.0 (14.0 \pm 1.4) ²
31	4	150-154 (152.5 \pm 1.9)	-	-	-	11.2-12.4 (11.8 \pm 0.6) ³

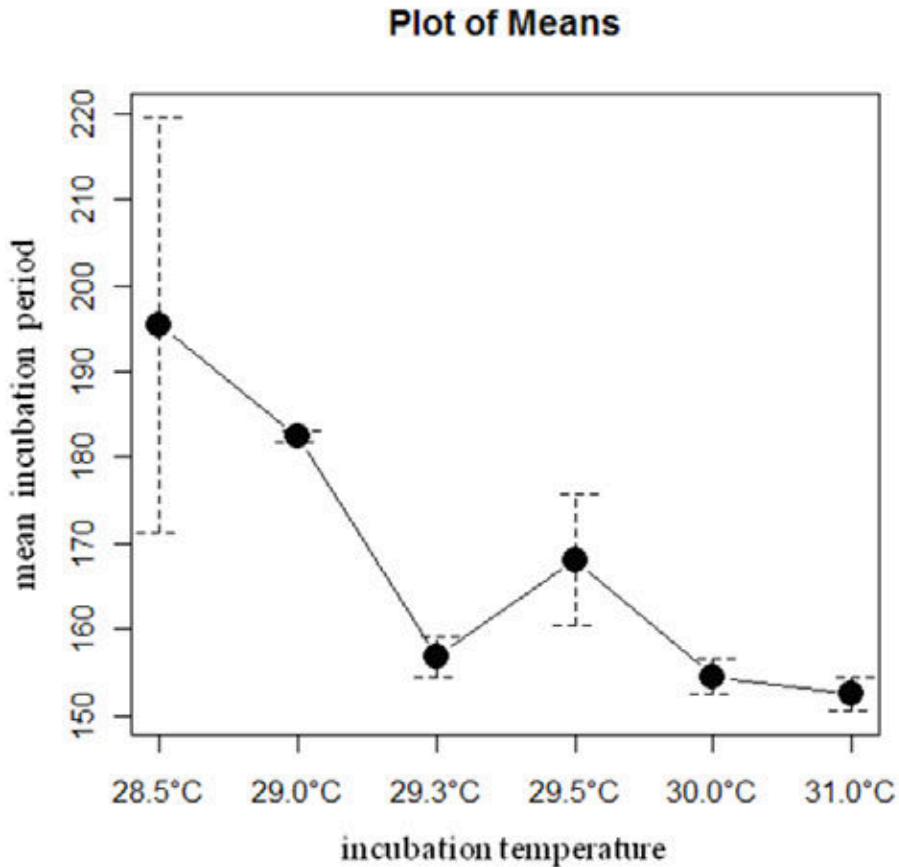


Fig. 7. Mean and standard deviation of incubation period for *V. macraei* in relation to incubation temperature; after own data (successful breeding at Cologne and Plzen Zoos) and data from Jacobs (2002), Dedlmar (2007) and Moldovan (2008).

temperatures varied from 28.5 to 31 °C, with 28.5 °C representing the most frequently used temperature for incubation. More than half of the incubated eggs of *V. macraei* (67%) hatched in all facilities independent of the incubation temperature. Most of the eggs which did not hatch proved to be infertile (21%). Incubation times ranged between 150 and 240 days, depending on the incubation climate. The incubation period generally declined with increasing incubation temperatures (Fig. 7, Table 4). Hatchlings measured 88 to 100 mm in SVL and 125 to 150 mm in TL (213 to 264 mm in total length). Eggs that were incubated at higher temperatures led to lower incubation periods and usually produced larger hatchlings (see Table 4). This trend suggests that higher incubation temperatures are more beneficial to the development of *V. macraei* clutches; however, this needs to be confirmed by further research. Sexual maturity seems to be reached by the age of about two years, as was shown by the male offspring from the Plzen Zoo which successfully copulated with the wild-caught female kept at Cologne Zoo. The age of this male was 26 months at the time of successful copulation and

it measured 320 mm in SVL and 645 mm in TL at that time. The sexual maturity of *V. prasinus* is also reached at an age of about two years (Greene, 2004).

Individual Recognition

In 2008, one of the hatchlings from the first clutch of *V. macraei* at Cologne Zoo was stolen from an exhibit accessible to the public. Because the juvenile specimen was not yet microchipped, this gave reason to study a possible individual recognition system for this species. Photographs from all hatchlings were evaluated and compared with the grown-up specimens. For every specimen, a characteristic neck pattern was detected which allowed for proper identification even after about 1.5 years, as discernible by Fig. 8. Although the borders of individual dark neck patterns may slightly change or become intermixed by lighter scales over the years, it still allows for an individual's identification. Thus, as an alternative method for recognizing individual specimens, it is recommended to photographically document the pattern on both sides of the neck. The characteristic neck



Fig. 8. The neck pattern of *V. macraei* may serve for the recognition of individuals as is shown here for the specimen depicted on the top of Fig. 5; above: immediately after hatching (20 Nov. 2007, photograph by **Norbert Rütz**), and below: 16 months later (27 March 2009, photograph by **Thomas Ziegler**).

pattern (left side) of the stolen specimen, consisting of three dark ball-like structures at the lower neck, is well discernible from a figure published in Ziegler (2008: 10) and in the November issue (Vol. 2, No. 4:148) of this journal (available at http://varanidae.org/Vol2_No4.pdf).

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