The Herpetological Bulletin 159, 2022: 1-5
RESEARCH ARTICLE

https://doi.org/10.33256/hb159.15

Reproductive husbandry of the rat snake *Elaphe moellendorffi*

MATTHEW COOK, LEAH J. WILLIAMS & IRI GILL*

North of England Zoological Society, Chester Zoo, Upton-by-Chester, Chester CH2 1LH, UK
*Corresponding author e-mail: I.gill@chesterzoo.org

ABSTRACT - Möllendorff's rat snake *Elaphe moellendorffi* is a large colubrid snake that has only been propagated a few times in captivity, predominantly in private collections. Chester Zoo successfully hatched 6 rat snakes in October 2019. Prior to introduction, the adult snakes were exposed to a cycling regime that simulated natural seasonality. Eggs were incubated and the young snakes hatched after 80-85 days and had their first slough 13-15 days post hatching. Hatch weights ranged between 19 and 20.6 g. Through a degree of manipulation, the neonates fed successfully 4 days after their first slough.

INTRODUCTION

Möllendorff's rat snake *Elaphe moellendorffi* (Boettger, 1886) (Fig. 1a) is a large colubrid. Adults are typically 180 cm to 250 cm long, weigh up to 2 kg (Gumprecht, 2004) and are sexually dimorphic with males being significantly larger and with much wider heads than females (Gumprecht, 2004). The species is confined to extreme southern China (Zhao & Alder, 1993; Zhou et al., 2012) and northern Vietnam (Schulz, 1996) being found at 30 m to 300 m a.s.l. (Zhou et al., 2012). They inhabit deciduous forest hillsides, the edges of rice fields, meadows and bamboo thickets near water (O'Shea, 2018; Zhou et al., 2012; Gumprecht, 2004) and favour crevices, rocky outcrops and karst limestone cave systems, particularly during the brumation period; this begins in November (Gumprecht, 2004). The distributional range of the species lies in the transition area between the tropics and sub-tropics with a climatic profile of long, warm summers and short, cool winters (Gumprecht, 2004). In January, temperatures are as low as 8 ^{o}C whereas during the warmest months, May to August, temperatures can be as high as 30 ^{o}C (World data, no date). These rat snakes have a dietary preference for mammals (O'Shea, 2018), although, adults have also been reported feeding on birds, lizards and frogs (Mehrtens 1987; Zhao, 1998; Gumprecht, 2004). Little is known about the reproductive biology of this species (Gumprecht, 2004), but like most other rat snakes it is oviparous (O'Shea, 2018) with clutch size ranging from 5-15 eggs (Gumprecht, 2004; Köhler, 2005; Zhao, 1998).

In 2012, the species was assessed by the IUCN as Vulnerable (Zhou et al., 2012). It is heavily traded with its meat used for food and medicinal liquor, whilst the skin is used for making clothing accessories (Zhou et al., 2012). In the 1950s the estimated population, in China, was 600,000, which had dropped to 50,000 in the 1990s (Zhao, 1998; Zhou, 2004). In captivity, the species has only rarely been propagated, mainly in private collections. Here we describe the captive husbandry and management of this species and provide the first documented breeding of the species within a European Zoo.

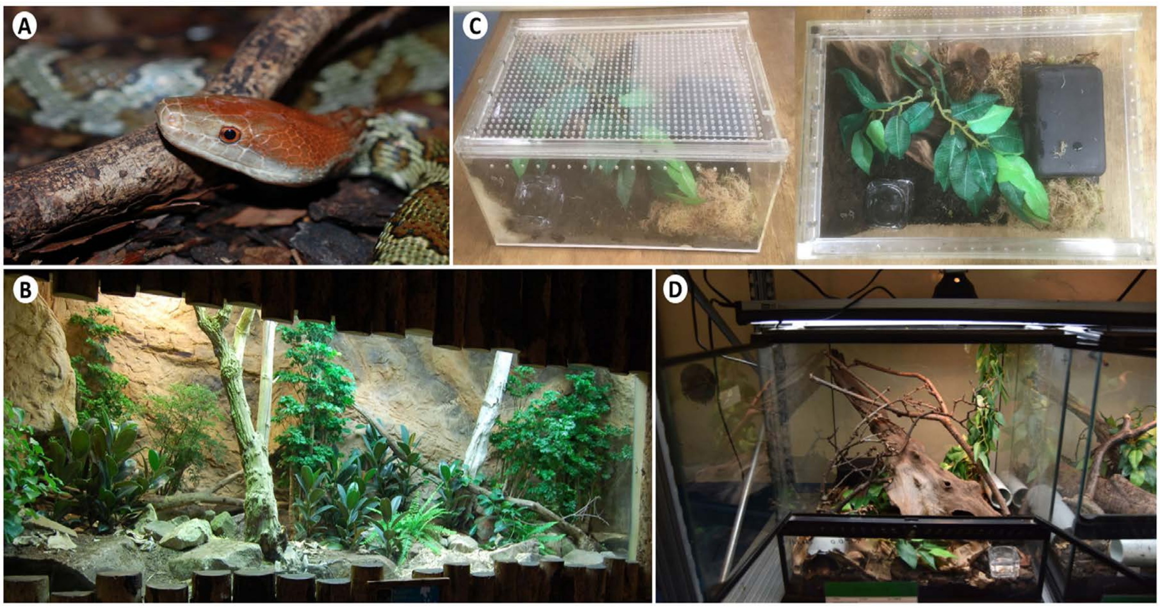

Figure 1. Captive care and husbandry of *E. moellendorffi* - **A**. Adult female *E. moellendorffi* at Chester Zoo, **B**. Display exhibit for adult snakes, **C**. Initial housing used for six *E. moellendorffi* hatchlings, **D**. Final set up of a 45 x 45 x 45 cm Exo-terra to house the hatchlings individually

Table 1. Enclosure parameters for the on-show breeding facility, the off-show brumation facility (male only), and the two neonate enclosures for the captive *E. moellendorffi*

	Display (breeding), Fig. 1b	Off-show (brumation)	Neonate Enclosure 1, Fig. 1c	Neonate Enclosure 2. Fig. 1d
Size (L x W x H)	350 x 120 x 150 cm	'Herptek' vivarium, 180 x 90 x 50 cm	Acrylic boxes 30 x 20 x 15 cm (reptiles.swelluk.com)	Exo-terra terrarium; two size 45 x 45 x 30 cm, two size 45 x 45 x 45 cm and two size 60 x 45 x 30 cm (Exoterra.com)
Substrate	Bark mulch and sand (70:30) and leaf litter	Composted bark fines and leaf litter	Soil with 50% sphagnum moss over	Bark fines (5 cm deep) and leaf litter and turned when overly damp.
Furnishings	Rocks to create multiple refuges, 4 large branches, rear and side rockwork and a pool for water	Wood, branches and commercial reptile hides large enough for full retreat, plus large water bowl	Plastic hide, tube and piece of wood. Small water bowl refreshed daily	Three hides (two with sphagnum moss), wood and branches. Small water bowl refreshed daily.
Planting	*Ficus elastica, F. lyrata* and *F. triangularis* (up to 1.5 m) and *Stephanotis floribunda* for ground cover	None	Plastic plant	Sphagnum moss and plastic plant
Lighting	2 x LightWave T5 Units (Growth Technology, UK)	54 W D3+ 12% Arcadia T5 lamp (Arcadia, UK)	Arcadia 54 W D3+ 12% T5 lamps (Arcadia, UK)	Arcadia 54W D3+ 6% T5 lamps (Arcadia, UK)
Photoperiod	8:16 (timer setting) but actually 10:14 due to natural daylight from the building roof.	9:15	9:15	9:15
Solar gradient*	0-3 UVI	0-3 UVI	0-1.5 UVI	0-2.8 UVI
Basking area	26-35 °C, Arcadia 160 W mercury vapour basking lamp (Arcadia, UK). UVI range 2-3	26-35 °C, 35 W UV-HID Solar Raptor lamp (Econlux GmbH, Germany) and a 50 W Arcadia 'Deep Heat Projector' (Arcadia, UK).	27.5 °C, Heat mat on between 09:30-16:30 h	27-32 °C, 54 W D3+ 6% T5 lamps (Arcadia, UK)
Temperature	Changed seasonally (see Fig. 1)	Autumn: 16-19 °C daytime, and 14-16 °C night time; Winter: 4-17 °C daytime 10-13 °C night time	23-25 °C daytime, 18-20 °C night time	20-26 °C daytime, 18-20 °C night time

*measured with Solarmeter 6.5R, Solar Light Company Inc. USA

METHODS & RESULTS

Study individuals

The breeding pair in this study were held at Chester Zoo in England. The male was captive bred and arrived at Chester Zoo in 2018 and was 13 years old. Two females were hatched in 2011 at Chester Zoo from eggs donated from a private collection. One female was selected for the breeding trials, the second female had poor body condition following a period of brumation and was therefore removed from the exhibit to an off-show area.

Enclosure design and parameters

Initially, both female specimens were housed in a large exhibit on display to visitors in Chester Zoo's 'Tropical Realm' (Fig. 1b, Table 1). The building ambient temperature was created by an air-handling unit and provided a temperature range of 18-25 °C. However, the building was also influenced by the external temperatures. Therefore, the enclosure itself was also affected by the external air temperature, especially as the back wall formed part of the buildings external wall. Within the enclosure, there were additional heat sources that increased the ambient and basking temperatures (Table 1). This, alongside turning on and off the hot air vent, enabled an effective seasonal fluctuation in temperature (Fig.2a). The temperatures were monitored and recorded using an ETI 'Therma-Hygrometer' and an ETI Mini Ray-temp infrared thermometer (Electronic Temperature Instruments LTD). In the summer, the enclosure was misted twice daily with tepid water. From September onwards, misting was reduced to once per day. At this time, care was taken only to mist the foliage and ensure the substrate did not become constantly damp. The frequency of misting was reduced further as the temperatures dropped until November when misting was suspended altogether for the brumation period.

The female snakes were fed one small weaner rat, weighing approx. 40 g, per week during the active season (March to October). They were offered food until they voluntarily refused at the start of the cool season (Table 2). After completing an isolated quarantine period of three months the male specimen was placed within the same display exhibit as the two female specimens. This was to ensure he was exposed to the same gradual drop in temperatures and to prepare for the brumation period. The male was last fed one large weaner rat, weighing approx. 75 g, one week prior to transfer from quarantine. After one month co-housing and following a gradual decline in temperature, the male was transferred to an off-show enclosure to complete his brumation period (Table 1). This was to ensure all specimens were healthy and ready to breed following brumation and the introduction could be controlled and observed.

Breeding

The male and breeding female each had eight feeds before they were introduced for breeding (see Fig. 2b for their weights). They were introduced late morning when the female was hidden in a burrow. Within one hour both animals were interacting with increased tongue flicking. The female exited the burrow to the middle of the enclosure where the male followed. Once the male reached the female, he began more courtship behaviours such as chin rubbing and body jerking on the female, whilst she remained in the same position. Both animals then moved into a more open space and the male aligned his body on top of the female. The tails intertwined and hemipenes were seen everted. The animals were left within the same enclosure from then on. Following this potential mating event, the female refused all food offered. It was confirmed by x-ray that the female was gravid with 10 eggs (see Table 2 for full timeline).

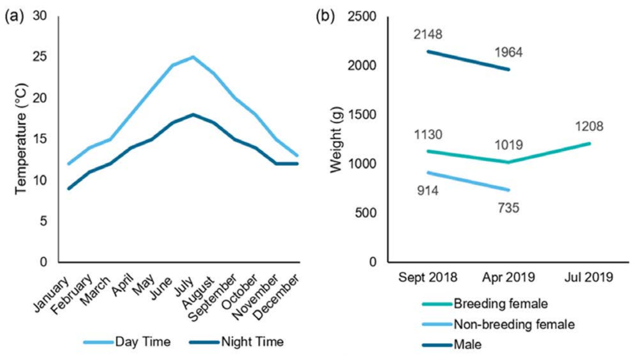

Figure 2. Physical conditions and body condition (weight) during the reproductive husbandry of *E.moellendorffi*- **(a)** Ambient temperatures of the display exhibit housing two female *E. moellendorfii*, recorded monthly in 2019, **(b)** Weight (g) for each snake pre-brumation (Sept 2018) and post-brumation (April 2019), and pre-laying (Jul 2019) for the breeding female

Egg deposition and incubation

A plastic storage box (L40 x W26 x H14 cm) with a lid was provided as a nesting site. The lid had a single entrance hole on the top. The substrate inside the nest box was damp sphagnum moss which filled approximately half of the box. The nest box was placed in the middle of the enclosure to be exposed to an ambient temperature of approximately 24 °C in the day and 21 °C at night. After 80 days, seven eggs were laid (Table 2), five of them adhered together (total weight 145 g) and the remaining two were joined (total weight 55 g). The eggs' mean dimensions were about 5.7 x 2.7 cm.

The eggs were transferred to a Pro hatch incubator (http://pro-racks.com/prohatch.html) set at a constant 27 °C where the substrate was a vermiculite water mixture (1:1 ratio). The incubation period was 80 to 85 days. Six neonates hatched successfully; the final egg contained a deformed specimen with a section of the lower body fused together in a fold.

Neonate management

After hatching, the neonate snakes were weighed (range 19-20.6 g) and then moved to individual rearing tanks (Table 1, Fig. 1c) within 24h. They all had their first slough 13-15 days after hatching. Subsequently, two individuals developed slight skin lesions. In one specimen a small patch of scales appeared worn away on the top of the head. As this was on the top of the head and not the tip of the snout, it was considered that it was not due to excessive rubbing on the lid or sides of the tank. A further two individuals developed similar patches. It

Table 2. Timeline of breeding events for the captive *E. moellendorffi*

Date	Breeding Event
26/07/2017	Females moved to display exhibit
28/09/2018	Females final feed
02/11/2018	Male added to display exhibit
02/12/2018	Male moved off-show for brumation
04/04/2019	All animals feeding
22/05/2019	Male introduced to breeding female
08/07/2019	Breeding female confirmed gravid with 10 eggs
25/07/2019	Female began oviposition
29/07/2019	7 of 10 eggs laid, final 3 eggs removed by veterinary intervention and discarded
12/10/2019	Neonates began to hatch
16/10/2019	Neonates emerged from 6 eggs
27/10/2019	First skin slough reported
31/10/2019	All neonates had fed

was decided to re-house the animals in different tanks to offer a wider thermogradient as well as a better humidity gradient (Table 1, Fig. 1d). This change in set up seemed to address the skin issues as there were no subsequent problems.

Neonate feeding

A day after the first slough a single new born mouse (pinkie), weighing about 1.6 g, was left outside the neonates' hides but no snake ate them. Two days after the first refusal, a pinkie was offered using forceps, which was successful. The remaining three specimens had completed their first slough by this stage. The successful strike method from forceps was used immediately this time and was successful in eliciting a feeding response. All neonates had eaten their first meal by 31st October. Although feeding could be achieved in this way, the methodology had to be further developed to ensure consistent success. The feeding process was found to be easier with the furnishings removed from the enclosure. The pinkie was offered from a distance via forceps to prevent the keeper's hand from intimidating the snake and hindering focus on the food. It was found that the best way to elicit a strike response was to poke the body and move towards the head with the food item. The most sensitive area to apply a slight pressure with the food item was around the neck. This frequently prompted the snake to strike sideways at the food item with mouth wide open. The pinkie was quickly orientated anteriorly into the snake's mouth. The neonates were never observed constricting their prey. Whilst in the process of swallowing the food item, the young snakes would frequently vibrate their tails. A few further techniques were developed for reluctant feeders. The front legs of the pinkie were cut off, as some individuals would snag their jaws on the pinkie's limb causing them to spit the food out. Some specimens had poor accuracy with their strikes which resulted in them biting at the substrate. To combat this issue, a layer of kitchen roll was placed on top of the substrate and dampened down before feeding. After a few weeks of feeding, they were offered two pinkies per feed. However, some animals regurgitated the prey. To avoid this, the neonate snakes were observed after feeding until they were active again, i.e. had digested their meal, which took 3 days. On the following day another pinkie would be offered. On occasion a pinkie would be left in the enclosure for a day to see if the snakes would start picking the food up on their own. At 7 months of age, 4 specimens began to feed in this way (at this stage the largest neonate weighed 25.1 g).

DISCUSSION

Here we have documented the first successful breeding of *E. moellendorfii* in a European Zoo. If others are to replicate this success, there are some important considerations for husbandry and management, namely seasonal fluctuations in environmental parameters and specific juvenile feeding techniques.

Most reptiles exhibit some seasonality in reproductive activity (Licht, 1972) and we believe that exposing the breeding *E. moellendorfii* to a natural environmental cycle, as they would experience in their home range, was key to this success. Although milder, the climate in Yunnan follows a similar seasonal pattern to that of Britain and therefore the influence of this seasonality on the breeding enclosure would have promoted reproductive cues for this species. This further supports the notion that captive management should be influenced by field data (Tapley & Acosta, 2010; Michaels et al., 2014), and follow an evidence-based approach to husbandry (Loughman, 2020). Where environmental field data are lacking for a species, other resources exist which can be used to close the knowledge gap, such as the work of Baines et al. (2016) on environmental microhabitat data from different biomes and other literature outlining regional environmental information taken from weather stations.

The seven-egg clutch observed in this study concurs with previous reports on both egg number; 6 to 12 eggs (Gumprecht, 2004; Köhler, 2005) and 5 to 15 eggs (Zhao, 1998), and egg size 5 to 7 cm (Zhao, 1998). The incubation period of around 80 days also corresponds with information from both Gumprecht (2004) and Köhler (2005) for eggs incubated at 27 °C.

Two main challenges were encountered with the offspring produced; skin lesions which occurred in the initial housing setup, and difficulties in getting the neonates to feed consistently. In the initial enclosures for the neonates the ambient humidity may have been too high with insufficient airflow which might have caused the skin lesions (Mitchell, 2004). These enclosures also had limited choice of places to hide. The larger enclosures to which the neonates were then moved appeared to resolve the problem by providing more space with better ventilation and wider thermo and photo gradients, giving the animals better opportunity to regulate within this environment.

The feeding of the neonates proved to be challenging. Security and environmental parameters are likely important contributing factors to success. The dietary preference of other neonate colubrid species, including Elaphe species, is frogs and lizards (Ernst & Ernst, 2003); it is likely to be similar for *E. moellendorfii*. Pinkies, however, were accepted following the techniques detailed in the results section (see 'Neonate feeding'). The snake's vision is very sensitive and any slight body movement from the keeper would prompt the snake to vibrate its tail and cease feeding or even regurgitate a partially swallowed food item. These defensive behaviours are suspected to be brought on by the presence of the keeper (Greene, 1988).

E. moellendorffi is poorly represented in the literature, particularly its reproductive biology (Gumprecht, 2004). This study offers an introductory contribution and reference point to the husbandry and breeding of this beautiful and interesting species.

ACKNOWLEDGEMENTS

The authors wish to thank the following: Herpetology department at Chester Zoo for husbandry management of the breeding animals and animals hatched; Richard Gibson, Auckland Zoo, for the donation of the female *E. moellendorffi*; Adam Bland for his comments and suggestions on the manuscript.

REFERENCES

Baines, F., Chattell, J., Dale, J., Garrick, D., Gill, I., Goetz, M., Skelton, T. & Swatman, M. (2016). How much UV-B does my reptile need? The UV-Tool, a guide to the selection of UV lighting for reptiles and amphibians in captivity. *Journal of Zoo and Aquarium Research* 4(1): 42 pp.

Ernst, C.H & Ernst, E.M. (2003). *Snakes of the United States and Canada*. Smithsonian Books. 680 pp.

Greene, H.W. (1988). Antipredator mechanisms in reptiles. In *Biology of the Reptilia*. Vol. 16, 1-152 pp. Gans, C. & Huey, R.B. (Eds.). Alan R. Liss, New York.

Gumprecht, A. (2004). *Die Blumennatter (Orthriophismoellendorffi)*. Natur und Tier-Verlag.

Köhler, G. (2005). *Incubation of Reptile Eggs*. Krieger Publishing Company, Malabar. 214 pp.

Licht, P. (1972). Environmental physiology of reptilian breeding cycles: role of temperature. *General and Comparative Endocrinology* 3: 477-488.

Loughman, Z.J. (2020). Utilization of natural history information in evidence based herpetoculture: A proposed protocol and case study with *Hydrodynastes gigas* (false water cobra). *Animals* 10 (11): 2021.

O'Shea, M. (2018). *The Book of Snakes: A Life-size Guide to Six Hundred Species from Around the World*. University of Chicago Press. 656 pp.

Mehrtens, J.M. (1987). *Living Snakes of the World in Color*. Sterling. 480 pp.

Michaels, C.J., Gini, B.F. & Preziosi, R.F. (2014). The importance of natural history and species-specific approaches in amphibian ex-situ conservation. *The Herpetological Journal* 24 (3): 135-145.

Mitchell, M.A. (2004). Snake care and husbandry. *Veterinary Clinics: Exotic Animal Practice* 7 (2): 421-446.

Schulz, K.D. (1996). *A Monograph of the Colubrid Snakes of the Genus Elaphe, Fitzinger*. KoeltzScientific Books. 439 pp.

Tapley, B. & Acosta, A.R. (2010). Distribution of *Typhlonectesnatans* in Colombia, environmental parameters and implications for captive husbandry. *The Herpetological Bulletin* 113: 23–29.

World data. (No date). *Climate for Yunnan, China*. https://www.worlddata.info/asia/china/climate-yunnan.php. Downloaded 1st April 2020.

Zhao, E. (1998). *China Red Data Book of Endangered Animals: Amphibia and Reptilia*. Endangered species scientific commission, PRC, Science press. 330 pp.

Zhao, E. & Adler, K. (1993). *Herpetology of China*. Society for the Study of Amphibians and Reptiles. 522 pp.

Zhou, Z., Lau, M. & Nguyen, T.Q. (2012). *Orthriophis moellendorfi*. *The IUCN Red List of Threatened Species* 2012: e.T192040A2031924. http://dx.doi.org/10.2305/IUCN.UK.2012-1.RLTS.T192040A2031924.en. Downloaded 31st March 2020.

Zhou, Z. & Jiang, Z. (2004). International trade status and crisis for snake species in China. *Conservation Biology* 18(5): 1386-1394.

Accepted: 1 October 2021