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First Breeding Report of the Pilbara Rock Monitor (*Varanus pilbarensis* Storr, 1980) in Spain with Taxonomic Comments on the Recently Described *V. hamersleyensis* Maryan *et al.*, 2014

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Abstract – The Pilbara rock monitor (*Varanus pilbarensis*) is an attractive Australian dwarf monitor lizard species which, due to its reddish-orange coloration and small body size, is a focal species for monitor keeping enthusiasts worldwide. However, very few published articles describing the captive husbandry and breeding of *V. pilbarensis* exist, even though it is clear from various photographs of these dwarf monitors on the internet, that private keepers are regularly breeding this species. This article describes the successful breeding of *V. pilbarensis* for the first time in a private collection in Spain. In addition, we make some taxonomic comments about the recently split-off *V. hamersleyensis* since intermediate phenotypes and hybrid crossings with *V. pilbarensis* are known to exist in captivity.

Introduction

The Pilbara rock monitor, *Varanus pilbarensis*, is a small monitor lizard that inhabits rocky outcrops in the arid Pilbara region of Western Australia (Storr, 1980). They are predominantly reddish-brown to orange in coloration, anteriorly turning dark brown or blackish on the second half of the body, and have a long rounded tail with black and cream-colored banding distally (Fig. 1). The dorsal coloration is pale to dark reddish-brown and/or orange, occasionally with irregular cross-bands on the head and neck. The dorsum is covered with deep brown ocelli featuring dark central spots. The black legs are mottled with cream-colored spots, and the throat and venter are greyish-white, irregularly spotted, and reticulated with grey markings (King, 2004). Total length (TL) can reach 50–55 cm, but only males reach this maximum size, with females growing only to 40–

45 cm TL. Apart from the larger body size, males have larger and more robust heads, as is often the case in dwarf monitor lizards of the subgenus *Odatria* (Aplin *et al.*, 2006).



Fig. 1. A specimen of *Varanus pilbarensis* from Port Hedland, Western Australia. Photograph courtesy of Gunther Schmida.

Today, *V. pilbarensis* is popular in North American, European, and Australian collections, where it is occasionally bred in captivity and commands high prices in the international pet trade. Within the European Union, *V. pilbarensis* is protected under EU Directive 338/97 (European Union, 1997), the EU-wide implementation of the international regulations of the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES 2017), where the species is listed under Appendix II along with most other monitor lizards. Australia banned the export of life native reptiles, amphibians, birds and mammals more than 50 years ago under the Environment Protection and Biodiversity Conservation Act (EPBC, 1999). According to a CITES trade database survey by Pernetta (2009), only 17 live specimens of *V. pilbarensis* have been legally exported out of Australia between 1975 and 2005. Our own analysis of the CITES trade database (2016), however, revealed that no *V. pilbarensis* specimens were ever exported. Therefore, most, if not all of the captive-bred specimens in private collections outside of Australia today have likely originated from illegally exported individuals.

Due to its colorful appearance and small body size, *V. pilbarensis* is a focal species for monitor keeping enthusiasts worldwide (Figs. 2 & 3). However, few reports describing its husbandry and breeding in captivity have been published (Eidenmüller & Langner, 1998; Retes & Bennett, 2001; Hörenberg, 2013), even though it is clear from various photographs on the internet that private

keepers are regularly breeding this species in captivity. This article describes the first successful breeding of *V. pilbarensis* in a private collection in Spain and provides some taxonomic comments about the recently split-off *V. hamersleyensis* since intermediate phenotypes and hybrid crossings with *V. pilbarensis* are known to exist in captivity.

Breeding Group

In March 2014, a subadult male *V. pilbarensis* (30 cm TL) was acquired from a reptile show in Madrid, Spain (Fig. 4). A few months later, two females were acquired from a British keeper. Both were mature individuals measuring 35 and 40 cm TL, respectively (see Fig. 5). Both females have the same color pattern, but differ slightly in appearance from the male. They exhibit a banded dorsal pattern of large light spots in contrast to the male that features black-bordered ocelli with black centers. Sexual dimorphism was evident by the wider and thicker head and neck of the male, as well as its enlarged paracloacal spur clusters (see Figs. 6-8). In December 2015, a third, noticeably older female was acquired from a private keeper. It was put under daily veterinary observation due to its poor physical condition, but died a few weeks later (see Camina Vega & Wefer, 2016).

Husbandry

The male was housed in its own terrarium measuring 100 x 60 x 60 cm (L x W x H), while the two younger females were kept together in a slightly larger enclosure measuring 120 x 60 x 60 cm. Each enclosure was divided into two sections with different microclimates including a basking area with a large pile of rocks, and a “shaded” area with a mix of cork tubes, cork walls and branches. Dried branches of the shrub *Retama sphaerocarpa* and rosemary (*Rosmarinus officinalis*)



Figs. 2 & 3. A European captive specimen of *V. cf. pilbarensis*. Photographs courtesy of **Edgar Wefer**.



Fig. 4. *Varanus pilbarensis* is an attractive Australian monitor lizard due to its colourful appearance and small body size. The adult male of the breeding group is pictured. Photograph by A. Camina Vega.



Fig. 5. The two female *V. pilbarensis*. Photograph by A. Camina Vega.



Figs. 6, 7 & 8. Differences in paraoccal spur clusters between the female (top) and male (bottom) *V. pilbarensis*. Note the broader tail base of the male due to the hemipenial pockets. Photographs by A. Camina Vega.

were used as decorative elements. *Varanus pilbarensis* can be very shy, so it was important to provide them with an abundance of hiding places such as large cork tubes, artificial caves and tree roots. The substrate consisted of a mixture of sand and sandy loam that measured 30–40 cm deep. Refuge sites were moistened twice per week. A water bowl was always available, but they seemed to prefer to drink when sprayed with water once to seven days per week, depending on the season.

Initially, the terrarium was equipped with a Solar Raptor lamp (Econlux GmbH, Köln, DE), but in order to improve ultraviolet radiation, UVB light was provided by an Arcadia (Arcadia Products, Redhill, UK) T5 desert reptile lamp (39W) covering Ferguson zones 3–4, depending on the distance (Baines *et al.*, 2016). One halogen spot lamp (35–50 W) and a white light (6500k) LED system were added to supply the correct visible light spectrum and create the basking spot. The temperature gradient remained virtually the same throughout the year (25–35 °C), with the highest temperatures of 40–45 °C recorded directly under the basking spot. Photoperiod was approximately 12:12 h (light:dark) during autumn and winter, and 14:10 h during spring and summer. The *V. pilbarensis* are most active between 1000 and 1300 h, and 1600 and 1800 h, but remain mostly hidden and become less active during winter.

For the first year, two different nesting boxes constructed of plastic and wood (each measuring 30 x 30 x 30 cm) were located in one corner of the shaded area of the enclosure and filled with a humid mix of sand and coir fiber, with vermiculite.

The group was predominantly fed live insects such as locusts and cockroaches and dusted with calcium and/or vitamin supplementation (Arcadia Earthpro-A) two times a week during the colder months and up to 4–5 times weekly during the warmer months. Prior to their introduction to one another, the animals were also offered dead baby mice.

Captive Reproduction

Although some private *V. pilbarensis* breeders keep their groups together year-round (A. Camina Vega, pers. obs.), it was decided to house the adults separately since it can be important to prepare females for the mating season by allowing them to feed and rest without interference from the male. During the mating season (May–September), the humidity of the terrarium was increased, spraying heavily by hand 1–2 times a day.

In early May 2015, both females exhibited



Fig. 9. The *V. pilbarensis* breeding group together. Photograph by A. Camina Vega.

distended abdomens as a result of what appeared to be vitellogenesis. It was therefore deemed a good time to either introduce the male to the two females (Fig. 9), or introduce each female to the male's enclosure separately.

When the male was introduced to the females (introductions 1, 2 and 5), it immediately began rubbing its cloaca on different elements of the terrarium, in what appeared to be territorial marking. He then approached each female multiple times while frequently moving the head from side to side and tongue-flicking at the females' bodies. Normally, the female being pursued would try to escape and hide from the male, so the male would redirect its focus to the other female. Although the females were not receptive to the male's courtship behaviors during the first day, the male persistently followed the females around the enclosure until one of them was finally trapped or consented to copulation (Fig 10). The male sometimes grabbed the females' heads and necks with its mouth during copulation. Copulation occurred several times over the course of 2–5 days. The male was separated 7–14 days later (depending on his interest), leaving the females alone in their enclosure.

On later occasions (introductions 3 and 4), each female was carefully and individually transferred to the male's terrarium. Initially upon each of their introductions, both females seemed very nervous and attempted to find shelter, but then settled down after a few minutes. Since *V. pilbarensis* is a species that can very easily be stressed, and since the females seemed to be more sensitive than the male in this regard (A. Camina Vega, pers. obs.), handling was kept to a minimum. The male's courtship behavior and copulation during these individual introductions were similar to those described



Fig. 10. Copulation. Photograph by A. Camina Vega.



Fig. 11. Hatchling *V. pilbarensis* emerging from its egg. Photograph by A. Camina Vega.

above. Females were separated 4–6 days after their introduction, based on their behavioral interactions with the male. After a 2–3 day break, the same procedure was repeated with the other female; this process was repeated until both females began to show clear signs of gravidity.

Two to three weeks after copulations had ceased, the females could be seen basking for extended periods of time throughout the day. They frequently refused food around one week prior to oviposition, and spent considerable time digging test holes in the substrate in the last few days before oviposition. Gestation, measured as the timespan between the last observed copulation and oviposition, was 4–6 weeks. Locating the eggs once laid proved to be difficult as both females ignored the nest boxes provided. When an abundance of holes were noticed in the substrate, their physical appearances were monitored several times a day. Eggs were usually buried under the pile of rocks in the corner of the enclosure. Following oviposition, it was important to wait at least 3–4 weeks for the females to recuperate and return to their original body weights before the male was introduced again. A total of two and three different clutches were collected from each female

between June and October 2015, respectively (Table 1). The clutches produced in June and July proved not to be viable and were discarded since the eggs developed mold and had soft and dry, mottled eggshells. Based on our experiences with other reptile species, the first clutch produced by an inexperienced female could be infertile (A. Camina Vega, pers. obs.).

All eggs were removed from the terrarium, buried in a plastic container filled with a mixture of vermiculite and water to an approximate ratio of 1:1 by weight, and placed inside an incubator constructed from a modified refrigerator. Non-viable eggs were discarded throughout incubation. The eggs were incubated at temperatures ranging from 27.5–28.5 °C and began to hatch after 91–105 days of incubation (see Fig. 11). Other successful breeders have experienced similar incubation periods, such as Eidenmüller & Langner (1998; incubated at 27±1°C for 99–136 days) and Hörenberg (2013; at 29.2 °C for 102 days). One egg was found with a fully developed, but deceased hatchling inside.

During their first few days, the hatchlings (see Figs. 12 & 13), which measured 13–14 cm TL, were housed separately in small terrariums (30 x 30 x 45 cm), each equipped with a basking spot and UV-B lamp

Table 1. Reproductive data for five clutches of *V. pilbarensis* eggs produced in 2015.

Clutch No.	Female	Date of oviposition	Clutch size	No. Fertile Eggs	Incubation temperature	Incubation period	No. Live hatchlings
1	1	22/6/2015	4	0	-	-	0
2	2	1/7/2015	3	0	-	-	0
3	1	2/8/2015	2	1	27.5-28.5 °C	-	0
4	2	27/8/2015	4	4	27.5-28 °C	91-100 days	2
5	1	2/10/2015	3	2	27.5-28.5 °C	105 days	1



Figs. 12 & 13. Basking one-week-old juvenile *V. pilbarensis*. Photographs by **A. Camina Vega**.

which provided the same environmental conditions as those offered to the parents. It may be necessary to house juvenile monitor lizards individually until they reach a larger size, due to concerns of cannibalism as observed in other *Varanus* species (e.g., *V. storri*; Eidenmüller, 2007); it is also easier to control food intake and monitor the fecal output of each specimen when housed individually. With the exception of one individual that died five days after hatching, probably due to a minor spinal deformity, the hatchlings began feeding after 10–12 days. They fed primarily on small crickets, cockroaches and isopods which were always supplemented with calcium. *Drosophila* sp. was also offered as enrichment.

Taxonomic Comments on the *V. pilbarensis* Species Group as Defined by Maryan *et al.* (2014)

Since the recent description of the new parapatric *V. hamersleyensis* that was taxonomically split-off from the southern distribution range of *V. pilbarensis* by Maryan *et al.* (2014), some experienced keepers have expressed doubts regarding the true identity of the first specimens of “*V. pilbarensis*” that were available outside of Australia because specimens with intermediate character states in coloration and pattern are known (Figs. 2 & 3). Additionally, successful keepers have informed us that the two different forms of *V. pilbarensis* as defined by Maryan *et al.* (2014) have



successfully interbred in European private collections (B. Eidenmüller & T. Hörenberg, pers. comm.). Thus, it seems plausible that some of the individuals that are presently traded on the international market or kept in zoos and private collections are (1) either pure *V. pilbarensis* and/or *V. hamersleyensis*, (2) hybrids between both taxa, or (3) hybrids between either of them and other taxa phenotypically similar to *V. pilbarensis* that have not yet been formally described (Figs. 14–16).

Hints for further taxonomic differentiation within *V. pilbarensis* seem to be evident from the phylogeny provided by Maryan *et al.* (2014), with an uncorrected sequence divergence of up to 6.6% from east to west of the species’ distribution range. There is, however, a sampling gap of nearly 200 km between these two alleged lineages. By comparison, the mean uncorrected divergence between samples of *V. pilbarensis* and *V. hamersleyensis* north and south of the Fortescue River Basin, respectively, is 10.2%. Thus, the taxonomic conclusions drawn by Maryan *et al.* (2014) from the phylogenetic data seem reasonable. However, the sample size is somewhat limited with only seven specimens each of *V. pilbarensis* and *V. hamersleyensis*,



Fig. 14. Pair of male (left) and female (right) *V. hamersleyensis*. Note the larger head of the male specimen. Photograph courtesy of Úrsula Burdon.



Fig. 15. *Varanus hamersleyensis* hatchlings. Photograph courtesy of Úrsula Burdon.



Fig. 16. Comparison between *V. pilbarensis* (right) and *V. hamersleyensis* (left). Note the differences in coloration and pattern. Photograph courtesy of Úrsula Burdon.

where an extended sampling could reveal genetically less-differentiated populations.

Morphologically, the distinction between *V. pilbarensis* and *V. hamersleyensis* seems less clear since the holotype of *V. pilbarensis* (as illustrated by Maryan *et al.*, 2014) lacks the dorsal ocelli that are often thought to be characteristic of this taxon (Storr, 1980), and instead shows small dark spots that tend to form short transverse rows on a light brown background coloration. This may, however, be the result of the alcohol preservation, since the live specimen depicted by Storr (1980) shows clear ocelli dorsally. In this regard, it is interesting to note that the color pattern of the offspring produced within the same clutch from a mixed pair of *V. "pilbarensis"* (*i.e.*,

one specimen of the *pilbarensis* sensu stricto phenotype and the other of the *hamersleyensis* color pattern) can vary greatly in captivity (see Eidenmüller & Langner, 1998), with bright red specimens exhibiting distinct ocelli hatching next to dark red individuals lacking nearly all dorsal markings (B. Eidenmüller, pers. comm.).

Noteworthy, Storr (1980) included into the type series of *V. pilbarensis* a specimen (WAM R13082, unsexed, from Woodstock Station, 21° 37' S; 118° 57' E) that was later identified as belonging to the *hamersleyensis* phenotype by Maryan *et al.* (2014). Moreover, Maryan *et al.* (2014) mentioned a record of a true *V. pilbarensis* (R110941) from south of the

Fortescue River Basin, from the north-western margin of the range of the newly described *V. hamersleyensis*. Therefore, it remains unclear if the ephemeral Fortescue River actually provides such a strong dispersal barrier for a spatial exchange and whether it effectively prevents gene flow and interbreeding between the monitor lizard populations north and south of it given the fact that it does not carry water all year-round (B. Eidenmüller, pers. comm.).

The fact that successful crossings have occurred between different forms of *V. pilbarensis* in captivity (and seems well possible in nature as is evident from the geographical information discussed above), raises doubts that two reproductively isolated populations (*i.e.*, two biological species according to Ernst Mayr's [1942] species concept) are involved, but rather two mostly allopatric subpopulations (*i.e.*, subspecies) that are separated by a valley and a temporary river crossing the distribution range of a species. Following the biological species concept, the sympatric occurrence of both forms throughout the Pilbara region with only little or no evidence of hybridization (as is the case with *V. pilbarensis* and several other monitor lizard species of the area such as *V. eremius* and *V. giganteus*) would strongly support their status as two phylogenetically (and morphologically) distinct species.

Nowadays, however, the biological species concept is often replaced by the evolutionary (Wiley, 1978) or phylogenetic (Cracraft, 1983) species concepts (Torstrom *et al.*, 2014), which more or less state that species are independently evolving and diagnosably distinct lineages. This rather simplified definition of species may, however, overestimate the diversity of organisms and does not distinguish between inter- and intraspecific differences, which is the variation observed between distinct species and within a given species. For the latter, the subspecies category (formerly called "variation" or "race") had been erected in biological systematics in the mid-19th century (Mayr, 1942; Wilson & Brown, 1953).

Today, however, the recognition of subspecies in taxonomy is not as popular as it once was, particularly in English-speaking countries. In contrast, for some authors (*e.g.*, Mulcahy, 2008; Koch *et al.*, 2010; Braby *et al.*, 2012), this taxonomic category still has its eligibility since the evolution of two daughter species from a single ancestral species (*i.e.*, the formation of new species by the divergence of populations) is a steady process of accumulating unique properties (so called "apomorphies"). The taxonomic challenge in this context is to define the point when two sister populations

have achieved the level of two distinct species. This is also known as the "species problem" (de Queiroz, 2005). Here, Torstrom *et al.* (2014), for instance, recommended using an integrative taxonomic approach (Dayrat, 2005) in order to objectively decide if populations represent different species or subspecies (see *e.g.*, Miralles, 2011).

In conclusion, we criticise that Maryan *et al.* (2014) did not explain their decision or how they taxonomically interpreted the differences they revealed in *V. pilbarensis*, and overlooked the possibility of applying the subspecies category to the southern population of the Hamersley Range. For future taxonomic studies on monitor lizards (and reptiles and amphibians in general), we therefore encourage herpetologists to act with more objectivity when allocating taxonomic categories to populations.

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