Chamaeleo Nr. 49, 35(1), pp. 49-58

Soil temperatures in the rainforest of Andasibe, Alaotra-Mangoro region, in the eastern highlands of Madagascar

Alexandra Negro

Harison Zoe Radimbiniaina

Thorsten Negro

With the successful keeping of a wide variety of chameleon species in herpetoculture, the challenge of incubating the eggs as successfully as possible also increases. The soil temperatures in the natural habitat of the respective chameleons could be the key to this. Soil temperatures in Madagascar have so far only been collected to a limited extent, on the one hand at a depth of 20 cm in Ankarafantsika [11], and on the other hand at a depth of only 3 cm in Ampijoroa, Kirindy and Ifaty [14]. These locations are all in the west and south-west of Madagascar. In 2018, we took the opportunity to measure soil temperatures in the eastern highlands of Madagascar, albeit on a much smaller scale than in the west of the island. However, the many positive responses from many chameleon keepers to the statistical analysis of the data from the west prompted us to publish the data from the eastern highlands as well.

Andasibe is located in the eastern highlands of Madagascar in the Alaotra-Mangoro region, only about 120 kilometres from the capital Antananarivo. The region is one of the most famous rainforest regions for ecotourism on the island [6,13]. Its fame is due not only to its proximity to the capital - only four hours by car - but also to the largest lemur found here, the indri. At the beginning of the 20th century, French botanists, herpetologists and adventurers used Andasibe as a base for expeditions into the rainforest. The old French name ‘Périnet’ was still in use long after the colonial era.

The rainforest near Andasibe is divided into the two national park sections Analamazaotra, located between the RN2 road and the village of Andasibe, and Mantadia about 10 km further north (Fig. 1). Analamazaotra covers only 8.1 km² of the total 120 km² area of the national park, but is by far the more frequently visited, more easily accessible and equipped with better trails. The rainforest directly opposite Analamazaotra, formerly the forest station of the national park, now belongs to the protected area of the Mitsinjo Association, a community-run organisation. The protected area covers around 7 square kilometres of rainforest. An even smaller rainforest area between Analamazaotra and Andasibe is managed by another community organisation and is called Vondron'olona miaro mitia ala, which is abbreviated to V.O.I.M.M.A. or V.O.I. and means ‘the people of the place love the forest’. This protected area covers just 0.4 km² and is located within sight of Andasibe railway station.

The rainforests of Analamazaotra, Mitsinjo and V.O.I.M.M.A. extend over altitudes between 900 and 1250 metres above sea level. The rainy season here runs from October to April and the dry season from May to September. However, it does not get really dry in Andasibe. The dry season here is characterised by cooler temperatures with moderate rainfall and, above all, cold nights. Air temperatures between 12 and 15°C at night are not uncommon in Andasibe during the dry season.

The rainforest near Andasibe is home to countless reptiles and amphibians. New species are discovered here almost every year. We regularly find males and females of the species *Brookesia superciliaris* (Kuhl, 1820), *Brookesia therezieni* (Brygoo und Domergue, 1970), *Calumma brevicorne* (Günther, 1879), *Calumma emelinae* (Prötzel, Scherz, Ratsoavina, Vences & Glaw, 2020), *Calumma nasutum* (Duméril & Bibron, 1836), *Calumma parsonii cristifer* (Methuen & Hewitt, 1913) and *Furcifer willsii* (Günther, 1890) [10]. *Calumma gastrotaenia* (Boulenger, 1888), *Calumma malthe* (Günther, 1879) and *Brookesia thieli* (Brygoo & Domergue, 1969) are somewhat rarer [10].

Data on clutch sizes of the species mentioned are scarce and mostly come from herpetoculture. *Brookesia superciliaris* and

Figure 1: Study area near Andasibe, map data from GoogleMyMaps © 2022 CNES / Airbus, Maxar Technologies.

Brookesia thieli, for example, are known to lay up to four eggs per clutch loosely on the ground [9,12]. Unfortunately, there is no information on clutch sizes, preferred egg-laying sites or burrow depths for the *Calumma* and *Furcifer* species found in Andasibe. There are only isolated reports of egg-laying sites within the genus *Furcifer*. In somewhat more closely related *Furcifer* species, the previously measured egg-laying depth varied between 9 and 20 cm.

Between 21 March 2018 and 5 February 2019, ground temperatures were measured approximately every other day in the three rainforest areas near Andasibe. Only in December 2018 no

Figure 2: A small part of the chameleons found by the authors in the rainforests near Andasibe: From top left to bottom right *Brookesia superciliaris, Calumma brevicorne, Calumma emelinae, Furcifer willsii, Calumma parsonii cristifer, Calumma nasutum, Calumma gastrotaenia* and *Calumma malthe.*

measurement was taken. The measuring points were selected using two methods: Firstly, measurements were taken where female chameleons had been observed laying eggs or where newly hatched young had just been found. In addition, randomly selected, shady spots in the forest were measured. During the dry season - i.e. outside the chameleon egg-laying season - all these sites were measured repeatedly. The soil at all measurement sites consisted mainly of moist soil. X4-Life soil testers (Lived non food GmbH, Friedrich-Seele-Str. 20, 38122 Braunschweig, Germany) were used for the measurements (Fig. 3). The soil testers have a measuring range of -9 to 50°C. The thermometers were inserted into the soil as far as they would go, which corresponds to a measuring depth of 20 cm. For each measurement, we waited three to five minutes until the reading on the display remained stable.

a) During the day. b) In the evening.

Figure 3: Measurement of soil temperature in the Analamazaotra rainforest with the X4-Life soil tester in January 2019 on different days.

Measurements were taken either in the morning between 7 am and 10am, at midday between 11.30 am and 2 pm or in the evening between 5 pm and 7pm. Only a few measurements were taken between 10 pm and midnight. Sunrise in Madagascar is between 05:15 and 06:30 in the morning and sunset is between 17:30 and 18:30 in the evening.

The arithmetic mean and the standard deviation for the available measurements were calculated for each month in order to track the annual course of the soil temperatures. Paired t-tests were used for comparisons between wet and dry season temperatures. All statistical calculations were performed using Microsoft Excel (Microsoft Ireland Operations Limited, 70 Sir Rogerson's Quay, Dublin, Ireland). $P \geq 0.05$ was defined as significant.

Month	In the morning	At noon	In the evening
March	22,0 ± 1,2	24,5 ± 1,5	25,0 ± 0,6
April	22,1 ± 1,7	22,5 ± 1,8	25,3 ± 0,8
May	20,5 ± 0,8	20,0 ± 0,2	20,8 ± 0,4
June	16,0 ± 0,3	16,5 ± 0,9	17,2 ± 1,2
July	16,3 ± 0,8	16,3 ± 0,8	16,1 ± 0,5
August	16,5 ± 0,5	17,7 ± 0,9	17,0 ± 0,3
September	17,4 ± 1,0	18,3 ± 1,2	19,6 ± 1,2
October	16,7 ± 0,5	18,0 ± 0,3	23,0 ± 0,5
November	21,2 ± 1,3	21,4 ± 1,5	22,0 ± 0,6
December	-	-	-
January	23,2 ± 1,5	25,4 ± 0,4	25,5 ± 1,1
February	23,4 ± 1,0	25,3 ± 0,6	25,1 ± 0,3

Table 1: Average monthly soil temperature data in Andasibe, Alaotra-Mangoro region, Madagascar, between March 2018 and February 2019 at a depth of 20 cm. Data are presented as mean ± standard deviation [°C].

A total of 418 soil temperature measurements were carried out and an estimated 70 different locations were measured. Table 1 shows an overview of the average soil temperatures for all months at the four different measurement times.

Due to a lack of data for December and thus a complete year, only a few comparisons could be made. However, even these show significant differences between the soil temperatures in the evening in the rainy and dry seasons ($P = 0.01$). During the dry season, the soil temperatures were significantly lower than during the rainy season. There were no significant differences in the monthly mean between the morning and midday temperatures between the rainy and dry seasons. Only the soil temperatures of two months with maximum values of the corresponding season, February (rainy season) and June and July (dry season), differed significantly ($P = 0.05$) from each other at all measured times. The soil temperatures in February were

Figure 4: Discussion of soil temperatures in Andasibe: Thorsten and Alex in the front, Edwin and Dimby in the back, José on the left.

significantly higher than those in June and July. The highest ground temperature during the observation period in Andasibe was 27°C on 29 March 2018. The lowest ground temperature was measured at 13°C at 06:11 on 22 June 2018.

As already observed with the ground temperatures in Ankarafantsika, there is also a difference between the most intensive periods of the rainy and dry seasons in Andasibe [11]. Night-time temperatures for Andasibe would have been very interesting, but for practical reasons they were only measured in very small numbers. Unfortunately, they were therefore not statistically analysable. The coldest temperature in the early morning at sunrise in Andasibe indicates that the temperatures at night during the dry season can even be below 15°C on individual peak days. The measurements also

confirm the assumption that chameleon eggs in Madagascar are exposed to high temperature fluctuations during incubation [11]. Even without measurements at night, we were able to determine a difference of 14°C between the warmest and coldest measured values. It is debatable whether strong temperature fluctuations during the incubation of chameleon eggs in the terrarium could possibly produce fitter young than eggs kept at the same temperature throughout. Studies in non-Madagascan chameleons have already shown that incubation under varying temperatures could increase the fitness of hatchlings [1,4,7]. Incubation at least with a cooler diapause has already proven to be indispensable in some Malagasy chameleon species in the past [2,3].

Of course, it is still questionable whether the continuous measurement of soil temperatures at a depth of 20 cm is significant for all chameleon species found. Ground chameleons such as *Brookesia superciliaris* can be safely excluded from this assumption, as they usually lay their eggs in the leaf layer above the ground or at very shallow soil depths [9,10,12]. Our own observations around Andasibe with *Calumma brevicorne* and *Calumma parsonii cristifer* suggest that burrow depths of up to 20 cm are also possible with these species. However, there is still a lack of scientific studies on a larger scale to prove the average burrow depth of the chameleon species occurring in Andasibe. The burrow depths of chameleons known to date are based on anecdotal reports [8,15].

The currently available knowledge on the incubation and development of chameleon eggs comes almost exclusively from herpetoculture. Of the chameleon species from the Andasibe region, written incubation data only exist for *Furcifer willsii* and *Calumma parsonii cristifer* [2,5]. The available soil temperatures can help to adjust incubation temperatures in chameleon breeding closer to the conditions of the natural habitat in Madagascar. In Madagascan tortoises, collected soil temperatures have already been successfully used for the incubation of eggs laid in captivity [14].

Finally, we would like to say a big thank you to local guide Edwin Randriamiaritsima in Andasibe, who has often been a great help to us in Andasibe over the last few years with his commitment and his good instinct for reptiles.

Literature

[1] Andrews, R.M. (2008): Effects of incubation temperature on growth and performance of the Veiled Chameleon (*Chamaeleo calyptratus*). Journal of Experimental Zoology **309** A: 435-446.

[2] Augustin, A. (2021): Nachzucht von *Calumma parsonii*. Chamaeleo **48**: 78-88.

[3] Augustin, A. (2011): Eine Inkubationsmethode für Eier von Calumma parsonii (hier der Variante *orange eye*). Chamaeleo **22**: 8-12.

[4] Ballen, C.J., Shine, R., Olsson, M.M. (2015): Developmental plasticity in an unusual animal: the effects of incubation temperature on behavior in chameleons. Behavior 152(**10**): 1307-1324.

[5] Bongers, W. (2007): Vorstellung von *Furcifer willsii*. Chamaeleo **34**: 20-21.

[6] Casse, T., Razafintsalama, M.H., Milhøj, A. (2022): A trade-off between conservation, development, and tourism in vicinity of the Andasibe-Mantadia National Park, Madagascar. SN Social Sciences **2** (12).

[7] Díaz-Paniagua, C., Cuadrado, M. (2003): Influence of incubation conditions on hatching success, embryo development and hatchling phenotype of common chameleon (*Chamaeleo chamaeleon*) eggs. Amphibia-Reptilia **24**(4): 429-440.

[8] Eppley, T.M. (2019): Evidence of spatiotemporal planning in a panther chameleon (*Furcifer pardalis*) on the Masoala Peninsula, Madagascar. Herpetology Notes **12**: 909-911.

[9] Flamme, A. (2005): Haltung und Nachzucht von *Brookesia thieli*. Chamaeleo **31**: 37-43.

[10] Glaw, F., Vences, M. (2007): A Field Guide to the Amphibians and Reptiles of Madagascar, Third edition. Cologne, Germany, Vences & Glaw Verlag.

[11] Laube, A., Radimbiniaina, H.Z., Negro, T. (2021): Jahresverlauf von Bodentemperaturen im Trockenwald von Ankarafantsika, Region Ambato-Boeny, West-Madagaskar. Chamaeleo **48**: 89-100.

[12] Lippe, R. (1994): Wieder eine gelungene Nachzucht eines Erdchamäleons (*Brookesia superciliaris*). Chamaeleo **12**: 3-4.

[13] Newsome, D., Hassell, S. (2014): Tourism and conservation in Madagascar: the importance of Andasibe National Park. Koedoe: African Protected Area Conservation and Science **56** (2).

[14] Pearson, D.W. (2013): Ecological husbandry and reproduction of Madagascar Spider (*Pyxis arachnoides*) and flat-tailed (*Pyxis planicauda*) tortoises. Proceedings of two workshops on the status, conservation, and biology of Malagasy tortoises and freshwater turtles. Chelonian Research Monographs 6.

[15] Rabearivony, J., Brady, L.D., Jenkins, R.K.B., Ravoahangimalala, O.R. (2007): Habitat use and abundance of a low-altitude chameleon assemblage in eastern Madagascar. Herpetological Journal **17**: 247-254.